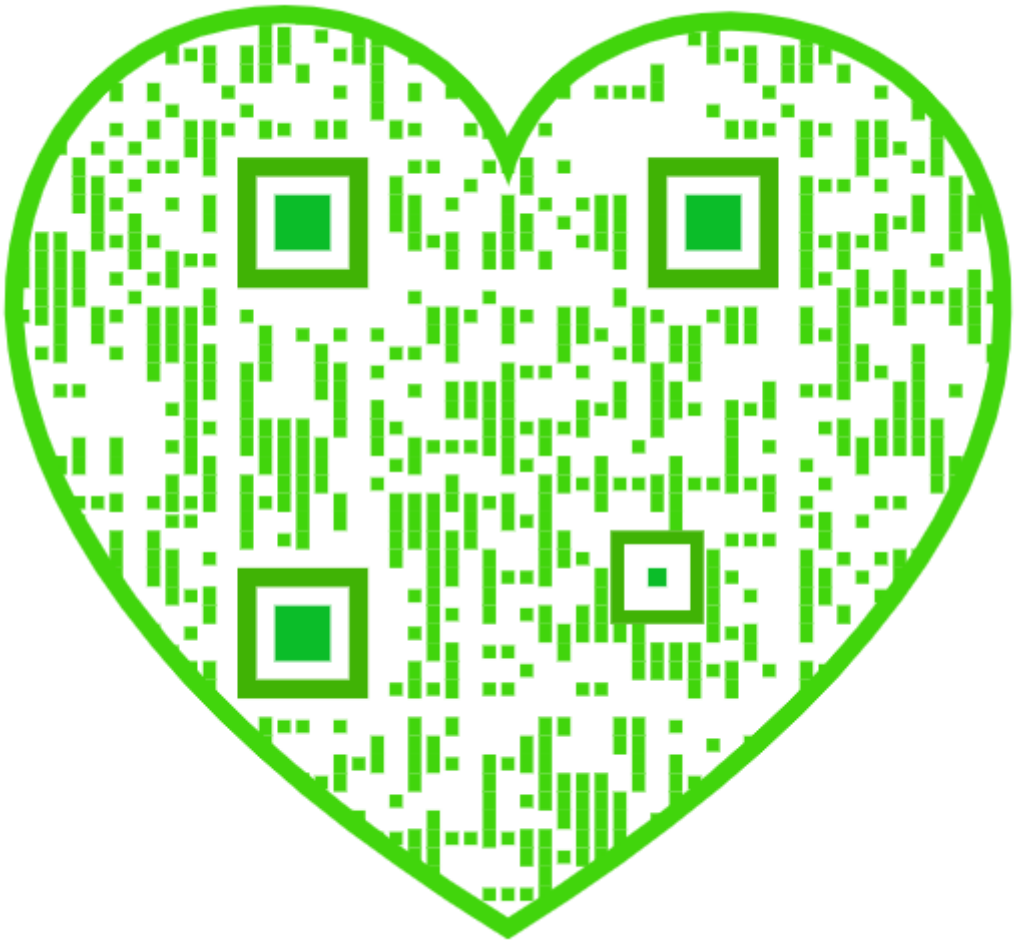

X-RAY OBSERVATIONS FOR FOREIGN BODIES and their LOCALISATION

To

M. le Docteur Béclère de l'Académie de Médecine, Chef du Service Central de Radiologie du Gouvernement Militaire de Paris.

In appreciation of the X-ray Service of the French Army, and of much personal kindness and encouragement.

X-RAY OBSERVATIONS FOR FOREIGN BODIES *and their* LOCALISATION

BY

CAPTAIN HAROLD C. GAGE, A.R.C., O.I.P.

CONSULTING RADIOGRAPHER TO THE AMERICAN RED CROSS HOSPITAL OF PARIS; RADIOGRAPHER IN CHARGE, MILITARY HOSPITAL V.R. 76, RIS ORANGIS, AND COMPLEMENTARY HOSPITALS

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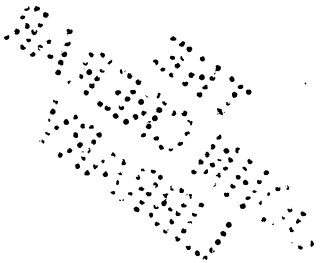

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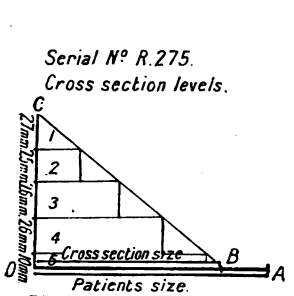
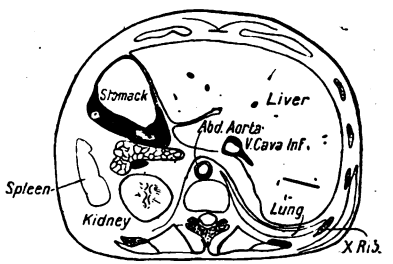


Fig. 1.



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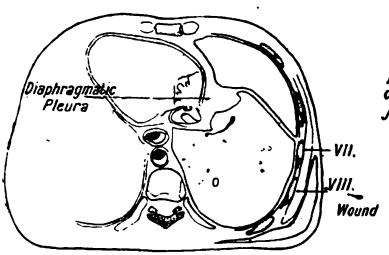

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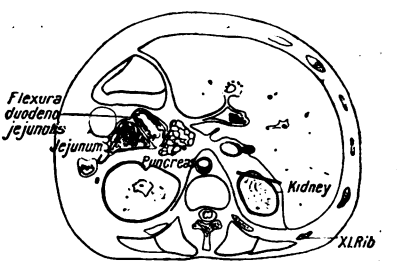

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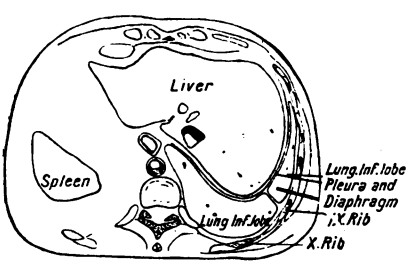

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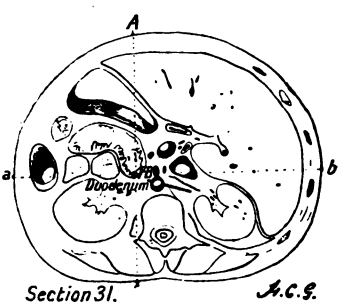

Section 31. A.C.G.

COMBINED LOCALISATION AND RECONSTRUCTION OF THE WOUND TRACT.

The passage of the projectile is marked in each section by the thick line indicating the tissues and organs probably injured. The subsequent history of the patient gives the following: Empyema, subphrenic and perirenal abscess, duodenal fistula and urinary fistula.

Frontispiece

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PREFACE

This small contribution to War Radiology was written by invitation in June, 1917. It was to have been a chapter on the localisation of foreign bodies in a work that was being compiled for the American Council of National Defence, but owing to the death of the Editor the publication was abandoned. The matter remains unchanged, with the exception of some small additions and appendices.

The Hospital at Ris Orangis has, during 1917 and 1918, been largely used as a training centre, and it is in response to the requests of many visitors to the clinic that the book is now published. It formed the basis of the lectures given on the subject.

These observations are based on the personal experience of the Author with the methods referred to in this book, constituting over 4 years application to the problems of war radiology (the first seven months were passed in an advanced ambulance within three miles of the line, the remainder has been spent at the base, apart from visits of detached duty), but for the majority of them no originality is claimed; and it is impossible to give personal acknowledgment to all who have generously helped me, or to the originator and every method mentioned. I should like, however, to acknowledge the great kindness and courtesy shown to me, and the information and experience so freely placed at my disposal, by my French colleagues. It is largely owing to their keen appreciation of the questions involved, and their unwearied application to the solution of the problems presented, that much progress has been made.

To Dr. Belot and Dr. Fraudet I am indebted for the privilege of inserting their method of localisation of foreign bodies in the eye, from their original work in the "Journal de Radiologie et d'Electrothérapie."

To Mr. H. Franze my thanks are due for the excellent drawing of many of the illustrations; also to my assistants, Mr. Beer, who provided several of the illustrations, and Miss Slater, whose help in revising the MS. has been invaluable.

INTRODUCTION

IT is almost superfluous to state that accurate localisation of foreign bodies is of prime necessity to the surgeon who is to remove them. No one realises this more than the surgeon who has wandered through the tissues in a fruitless search for a foreign body which he knows is somewhere there, but the exact location of which has not been made clear to him. In other words, a localisation, to be practical and successful, must not only be accurate but must have been recorded on the patient in such a manner as to be clear to the surgeon as well as to the radiographer. Moreover, it is quite essential that the surface marks from which the foreign body is oriented be so situated, and of such number as to obviate, in so far as possible, the errors that may arise from the impossibility of re-establishing on the operating table the exact position occupied by the limb or body during localisation on the X-ray table. For example, a report from the radiographer that the foreign body lies so many centimetres below a mark on the skin is insufficient, and to a certain degree dangerous, in that it affords an inexperienced surgeon an unjustifiable confidence in his ability to find it. The additional four or five minutes on the X-ray table needed to record a localisation from which a surgeon may work with certainty are much better spared than a longer time spent by the operating team in an ill-directed search—not to mention the consequent unnecessary mutilation.

Two years experience with the exceedingly simple and ingenious method of Localisation by Three Intersecting Lines, developed and perfected by Mr. Gage, has convinced the writer that it is the most practicable for the majority of cases. The three lines joining the three pairs of marks on the skin are readily pictured, and the position and relations of the foreign body consequently more clearly visualised than is possible by any other system. While mechanical aids may be used in addition they are very rarely necessary, which adds greatly to the practicability of the method for institutions where the cost of such apparatus would not warrant its possession. A proof of the value of the method is the remarkable record made by it in the hospital at Ris Orangis. A total of 306 localisations

resulted in 302 successful removals; in two cases the search was abandoned on account of the danger of wounding important anatomical structures, and only two localisations were unsuccessful.

Mr. Gage's experience, his great skill, and his knowledge of physical problems, lend great weight to his remarks and observations. No one can realise this more than those who, like the writer, have had the great privilege and the pleasure of working with him.

JOSEPH A. BLAKE,
Colonel, Medical Corps, U.S.A.

X-RAY OBSERVATIONS FOR FOREIGN BODIES AND THEIR LOCALISATION

General Installation.

The equipment for the generation of the electric current necessary to operate the X-ray tube for localisation of foreign bodies needs nothing special beyond the requisites for ordinary radiography and fluoroscopy. If the opportunity for choice occurs a coil outfit should be selected, as it undoubtedly has points in its favour for use in the field as against the high tension transformer.* For general hospital work, where instantaneous pictures of organs in motion are a daily necessity, the latter is indispensable, but the percentage of this work is almost nil in war surgery.

The coil should be given preference, briefly for the following reasons: it is easily portable, and gives better screen illumination for a given milliampereage, with a diminished risk of burns to both patient and operator; the proportion of fluoroscopic examinations is much greater than that of plates.

Details needing special attention apart from the instrumentation of any given method of localisation are: first, a rigid X-ray table, with a convenient under-table trolley to carry the tube in a well protected shield or box, and giving longitudinal and cross displacement that can be definitely controlled and measured; second, and almost first in importance, the tube holders must be such as to give convenient means of exactly centering the tube to a mechanical closing diaphragm that shall close absolutely in a central position. While many other desirable features might be added, these are imperative, and with them the most exacting work can be done with absolute certainty.

* The advent of the new radiator self-rectifying Coolidge tube and the American Army Portable Unit, is such an advance as to constitute a revolution in X-ray apparatus; its simplicity, efficiency, and portability are such that it may, and probably will, supplant the coil.

Darkening the Room.

Where possible ample room should be provided for the X-ray department. The tendency is to give any small odd room over to this work, which can but cripple the efficiency to a serious extent. In the X-ray room, work has to be done of the most tedious and exacting nature, which under unfavourable conditions becomes intolerable and shows itself in the results. Let it not be forgotten that the X-ray department in war surgery is second in importance to nothing in the whole hospital, and its quarters must be good, airy, and spacious; many people must work there; patients are frequently very sick, and the wounds smell badly; besides, the room is often required for an operating room for removal of foreign bodies under screen control, and for the reduction of fractures.

Darkening and ventilation are difficult problems, but for the sake of efficiency they must be solved. The window should always be accessible to be thrown open for airing between cases, while the operator wears coloured spectacles to preserve the adaptation of his eyes. The artificial lighting should be under control by a small resistance, in order that while changing position of the patient, etc., it may be diminished to a minimum; it should be preferably of red or violet colour. In advanced field use the cryptoscope is invaluable, and its best form will be described later. But whether the cryptoscope is used or the room darkened, care must be taken that not one penetrating ray can enter, in order that in a foreign body examination the smallest fragment may not be missed.

Protection.

This must, of course, be efficient. First see that the tube is enclosed in a ray-proof cupule or box, which the radiographer should test personally with the screen and if necessary reinforce. To test the lead glass of a fluorescent screen, should a second screen not be at hand, project the rays through the glass, and if fluorescence is produced discard for a denser glass or add a second. Handle covers and gloves should be lined and not made of plain lead impregnated rubber. Work

with as small a diaphragm opening as possible; do not place yourself or your fingers in the direct beam, and you are safe.

Diaphragm.

The type to be preferred is one that closes with one controlling handle and always on its exact centre. It should close with ease in order that the tube may not be displaced at the same time. It will be found that few, if any, of these diaphragms are in themselves efficient; they are always flat, and as hard penetrating rays are mostly used, many secondary rays are generated, producing diffusion and spoiling the definition; consequently, it will be found of infinite advantage to provide in addition a simple cylindrical diaphragm mounted on sheet lead to place over the mechanical one. Provide a cylinder of the smallest diameter that will suit you, and you will be amply repaid in the clear definition and in the assurance that you are letting nothing pass.

The Tube.

Although in some localising methods it is preferable to use the overhead tube or vertical screening stand, much of the work will be carried out—general screening, operating with fluoroscopic aid, etc.—in the horizontal position with the under-table tube. The choice of the tube is of some importance; therefore let it be a well formed, flexible tube, preferably water cooled, for it is worth much during an operative procedure to be relieved of all anxiety as to its welfare and efficiency. When formed, guard it and nurse it well. The focus need not be of the sharpest, but must not be too wide. In choosing a tube, should it not centre well, discard it, as it will lead to inaccuracy and disappointment. See always that its anticathode and anode are not accidentally disconnected, or its wandering focus will lead to confusion. A foot switch control is almost indispensable and may save you many steps and tubes.

The penetration of the tube for general observation should be represented by a spark gap of about 5½ to 6 in., although a softer degree will give better contrasts, and a 7 and 8 in.

gap may be required in observations for foreign bodies superimposed on the vertebræ, and for examination of stout patients. An adjustable series spark is a valuable addition for regulating the tube penetrations and should always be fitted to the apparatus.

Foreign Bodies—Their Nature and Shadow.

The visibility of a foreign body by X rays on plate or

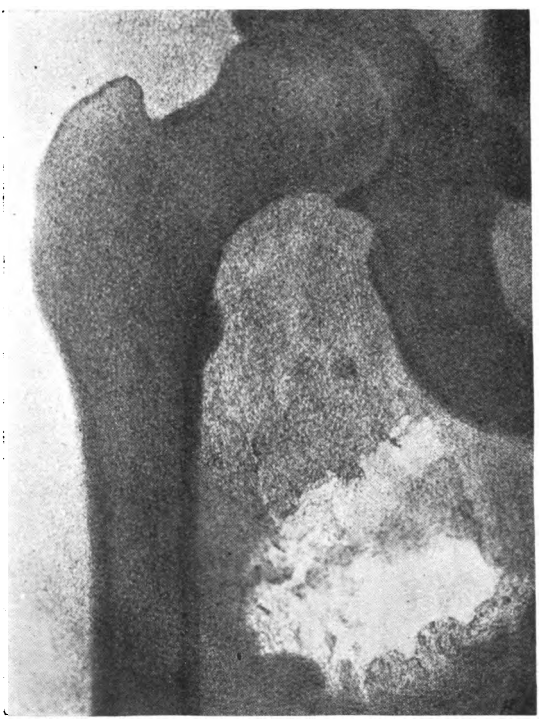
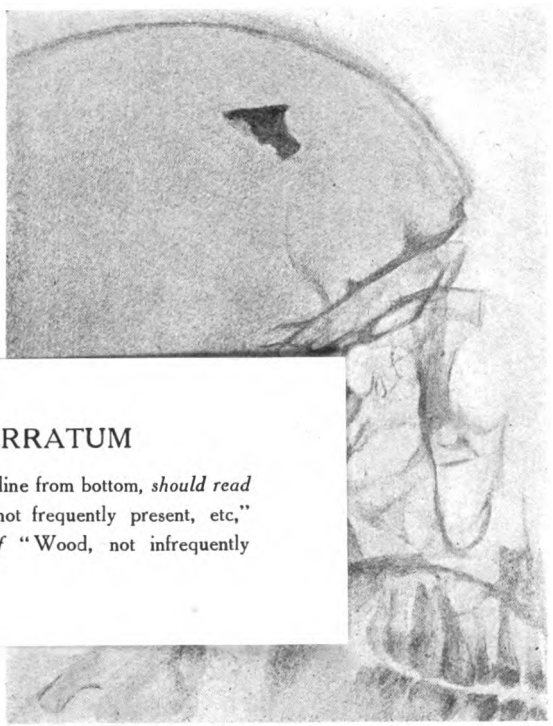


Illustration 1.
Radiographic appearance of wood in the soft tissues of the thigh. Equivalent spark gap 2 inches, 4 milliamp.-minutes.

screen is (apart from its size) entirely a question of its atomic weight, in contrast to that of the tissues in which it rests. For this reason different metals and materials throw a different degree of shadow. It must also be noted that change in the penetration of the tube will change the apparent density of a

given material. This is valuable in the differentiation of calcified glands, superimposed bones, bone fragments, etc.

Pieces of shell, shrapnel balls and rifle bullets, nails and metallic refuse from hand grenades, and lead splutterings will be easily detected, while thin bullet casing and fragments of aluminium are more difficult—the latter almost impossible if



ERRATUM

Page 5, third line from bottom, *should read* "**Wood**, not frequently present, etc," *instead of* "Wood, not infrequently present."

Illustration 2.
The casing of a rifle bullet stripped and remaining in the tissues.

not of considerable size and in a thin part of the body. Clothing throws no shadow unless it is impregnated with some denser material. Wood, not infrequently present in the soft tissues, is not discoverable with the screen, but may be found by plating, if the tube is of low penetration. (Illustration 1.)

General Examinations.

The search for foreign bodies should not be confined to the region of the wound, but a thorough general examination should be made, especially if there is only one wound, *i.e.*, the wound of entrance. Never be led to suppose that a wound of exit negatives the possibility of a lodged foreign body. Many bullets strip their jackets in transit (Illustration 2), or

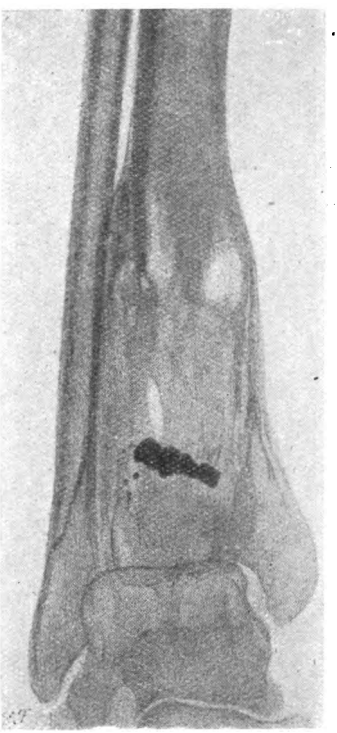


Illustration 3.
Sinus injection with bismuth simulating a lead foreign body with splutterings.

shell fragments are separated by contact with bony structures. A foreign body may travel a great distance and take a very unusual course. In a case with a wound of entrance over the left deltoid, a shrapnel ball was recovered from the superficial tissues of the left buttock, having traversed the length of the body externally to the ribs. The case was

reported negative for foreign bodies on several occasions. Ultimately the ball manifested itself by causing an abscess.

In the examination for foreign bodies errors easily occur, due to buttons on the clothing, coins or articles in the pyjamas pocket or round the neck, pins, etc., in dressings, or drains. Therefore all gowns should be tied with tape, and dressings be fixed with adhesive, or the parts absolutely denuded. Bone-plates fixing fractures, wire sutures, and Murphy's buttons must not be confused, and accumulations of metallic ointment, iodoform, or bismuth paste, show a very decided shadow easily misinterpreted. (Illustration 3.)

Photographic Faults.

When reading plates, one must bear in mind photographic faults caused by air bubbles in development or imperfections in the emulsion; flaws in intensification screens can be a further source of error.

Anatomical Densities.

Attention should be given to the possibilities of either fluoroscopic or radiographic misinterpretation of the shadow cast by calcified glands, gall stones, stones in the kidney ureter and bladder, phleboliths, or superimposed bones, such as the pisiform, the spinous processes of the vertebræ, sesamoids, the superior margin of the acetabulum, etc., but with care these can be differentiated by their comparative densities. When the fluoroscopic examination is uncertain a plate should be taken. With organs in motion, when it is not possible to take instantaneous radiographs, fluoroscopic observations are more reliable.

Tube Centering.*

In all radiographic technique the position of the tube in relation to patient and plate is very important. In no instance is it more so than in localising foreign bodies, to accomplish which it is necessary to isolate and use the central vertical beam of rays (or normal ray, as it is termed); and at

* *Archives of Radiology and Electrotherapy*, May, 1918.

times, to note its incidence on the plate, screen, or patient. Most modern tube carriers and diaphragms have a mechanical attachment, which enables this adjustment to be made with ease. By this appliance the tube can be moved in any direction, until it is so placed that the normal ray passes through the centre of the diaphragm.

Illustration 4, Fig 1, shows (*a*) the anticathode, (*b c*) the normal ray passing through (*m*) a tube, in which are (*n*, *n'*)

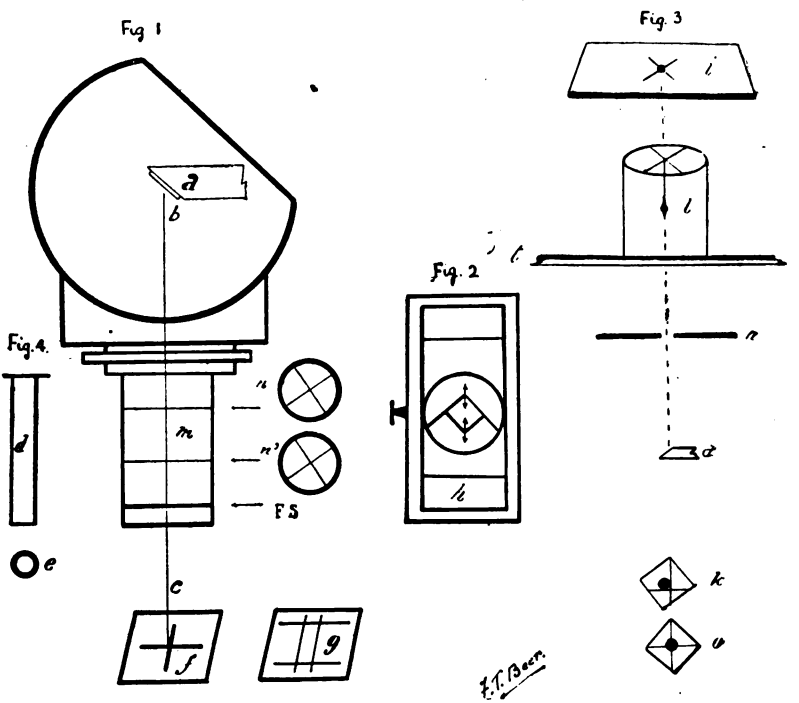


Illustration 4.

two sets of cross wires, and (*F.S.*) a small fluorescent screen. (*f*) Shows the appearance on the screen when the tube has been accurately centered, the shadows of the two crosses being superimposed on the screen and forming one image only; (*g*) illustrates the screen appearance before centering. When centered, the apparatus (*m*) is removed and replaced by the diaphragm (*h*) (Fig. 2), which closes down on the same

centre. Fig. 3 shows a convenient method of centering an under-table tube or verifying its correctness. On the table top is placed a small papier maché box (a lady's powder puff box will do well), across the top of which two wires are stretched at right angles, while from their intersection hangs a small

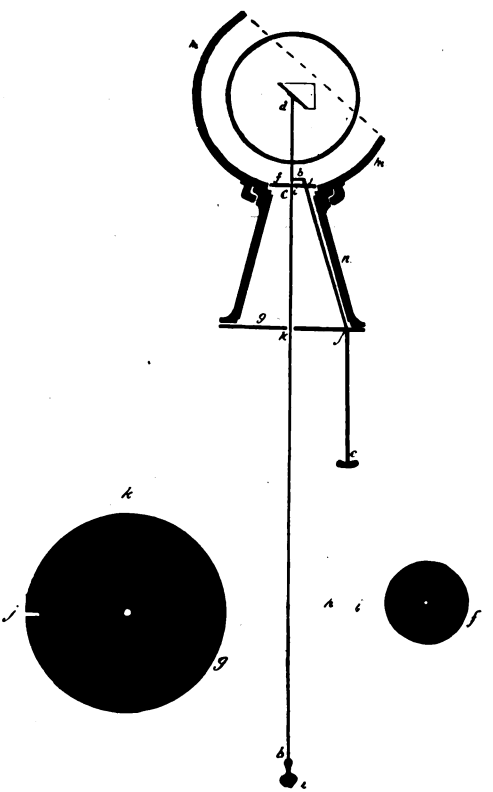


Illustration 5.

a, Anticathode of tube. *b*, Path of normal ray. *m n*, Cupule and diaphragm in position. *g*, A disc of cardboard, aperture in the centre ¼ in. in diameter. *f*, A smaller disc, with tiny central perforation, and second hole for the return of the cord supporting the plumb-bob *l*. In use the tube stand is adjusted until the cord hangs in the centre of the perforation *k*, when the plumb-bob may be lowered and the incidence of the normal ray recorded. This simple contrivance can be left attached, the metal portion withdrawn to the side during exposure.

plumb-bob on a fine cord dipping into oil, with which the box is partially filled. If the tube is now brought under this

small contrivance, and its projection on the screen viewed with the diaphragm closed down, a correctly centered tube will give the appearance shown at *O*, while a badly centered tube that shown at *K*. It is impossible to give too much emphasis to the importance of accurate centering.

When it is desirable to record on a plate or limb the incidence of the normal ray, or to adjust cross wires to it, when using the overhead tube, two pieces of cardboard and a plumb line will suffice admirably. Illustrations 5 and 6 show their preparation and adjustment.

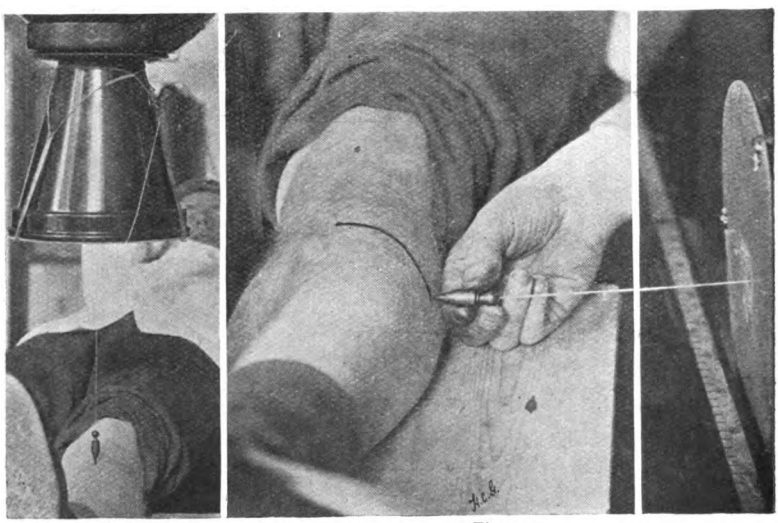


Fig. 1. Fig. 2

Illustration 6.
Vertical and lateral adjustment.

Provisional Localisation at First Observation.

When a foreign body is found, the diaphragm should be closed down, and the adjustment made to include the foreign body in the narrow beam of rays projected vertically from the tube. A small metallic circle on the end of a wooden handle may now be inserted under the screen until its image is projected as encircling the foreign body; the skin may be marked through this ring with an indelible pencil, and the ring with-

drawn; or if desired, one of the mechanical appliances shown in Illustration 7 can be used. This gives a point on the skin vertically over the foreign body. To ascertain its depth a metal rod may now be taken ; the spark gap indicator will do well. The rod is held horizontally, and its point is placed upon the spot previously marked. The diaphragm should now be opened and the metal rod lowered across the limb, keeping its point in contact with the circumference. Now displace the tube longitudinally and the shadows of the foreign body and the point of the rod will travel in the opposite direction; if they both travel the same distance the point of the rod is at the depth of the foreign body, and its position can be marked on the skin as before ; should the foreign body travel further it is necessary to lower the rod still further till the displacement

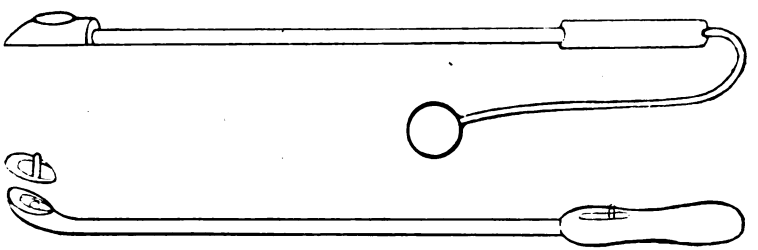


Illustration 7.

A. Pneumatic marker (Hernaman-Johnson), Watson, London.
B. Mechanical marker—Gaiffe, Paris.

is equal. Care should be taken to have the screen horizontal, and to move the rod in a plane perpendicular to the line of displacement of the anticathode. In this crude manner it is possible to give the approximate position of superficial foreign bodies for removal with the vibrator, or to decide the necessity for exact localisation. The process takes but a few seconds. To measure the distance travelled by the shadows a sheet of celluloid, ruled in narrow lines, may be placed on the fluorescent screen. In this way a reliable guide is furnished.

Another screen method, which gives a rapid and accurate measure of the depth of a foreign body, is that of Strohl. The necessary apparatus can be improvised with very little trouble, and is especially suitable for use at a casualty clearing station,

where a large number of cases must be dealt with in the minimum time. All that is required is a pair of fine parallel wires, mounted on the upper surface of the mechanical diaphragm of the under-table tube, at equal distances from the centre, and lying across the most convenient line of displacement of the tube. (If the wires are fixed across a broad strip

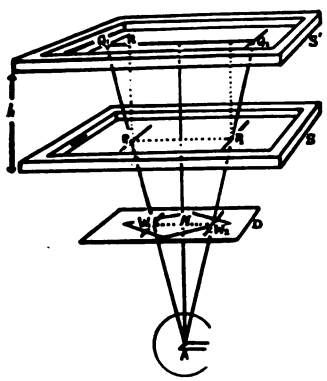


Fig. 1

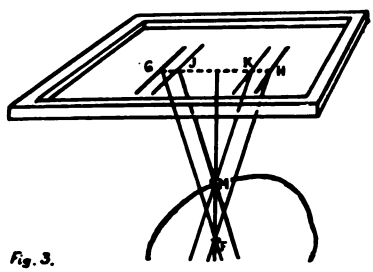


Fig. 3.

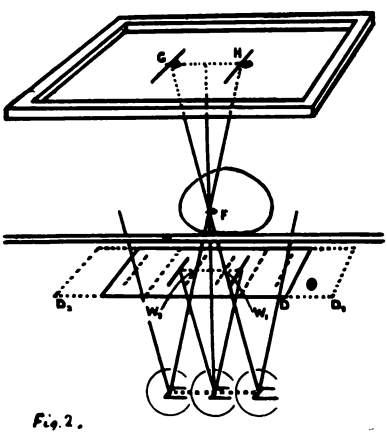


Fig. 2.

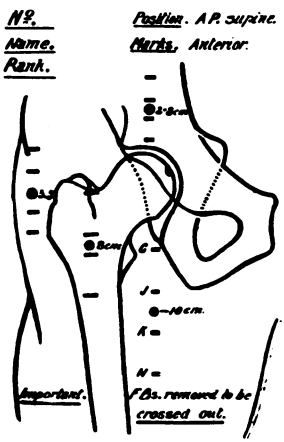


Fig. 4.

Illustration 8.

of adhesive tape, they can be mounted and dismounted at any time in a few moments.) To simplify the calculation of the depth of the foreign body, it is most convenient to make the distance apart for the wires half the height from the anti-cathode to the diaphragm (see Illustration 8, Fig. 1, where

Fig. 5.

Fig. 5.

Illustration 8.

This illustration may be viewed with a hand stereoscope.

W_1 W_2 is half A N); this distance should be found as accurately as possible by measurement. To test the adjustment, place the screen S over the tube, and measure the distance P_1 P_2 between the shadows of the two wires. Then raise the screen through a carefully measured height h, and note the new distance Q_1 Q_2 between the shadows. As will be seen at once, from the similarity of the triangles A W_1 N, P_1 Q_1 R, the difference Q_1 Q_2—P_1 P_2 should be exactly half h. If it is less than half h, the wires should be separated; if it is more they must be brought nearer together, until, on testing as before, the adjustment is found to be correct.

In using the apparatus, the foreign body (F, Fig. 2) is first found with a small diaphragm opening, and the tube is shifted until the normal ray passes through it; the point of emergence is then marked on the skin. If it can conveniently be done, the screen is brought close down to the skin (in this position the marking is facilitated if a perforated screen is used). The diaphragm is then opened and the tube shifted until the shadow of one of the wires (W_1, Fig. 2) passes through a definite point in the foreign body, and the position of this shadow (G) is marked on the glass of the screen with ink or a grease pencil. The tube is shifted and the shadow of the second wire (W_2) made to pass through the same point of the foreign body; this second position (H) is marked on the screen as before. Then the depth of F below the screen is twice the distance G H.

If it is not feasible to bring the screen into contact with the surface of the limb at the point of emergence of the normal ray through F, the best method is to place a small metallic body at this point (see M, Fig. 3), so that the shadows of F and M are exactly superposed. Then, by shifting the tube as before, the points on the screen where the shadows of the wires pass through M are marked, as was previously done for F; the distance J K is also measured and subtracted from G H; this difference multiplied by 2 is the depth of F below M, *i.e.*, below the marked point on the skin.

Fig. 4 (Illustration 8) shows a chart prepared in this way, where four different foreign bodies in the region of the hip are

clearly shown, with their respective depths. Such a chart is best made on celluloid, as explained below.

Stereoscopic Tracings from the Screen.

Such tracings are easily made. Of course they are not so good as plates, but if from pressure of work, or for any other reason, plates cannot be taken, and the relation of a foreign

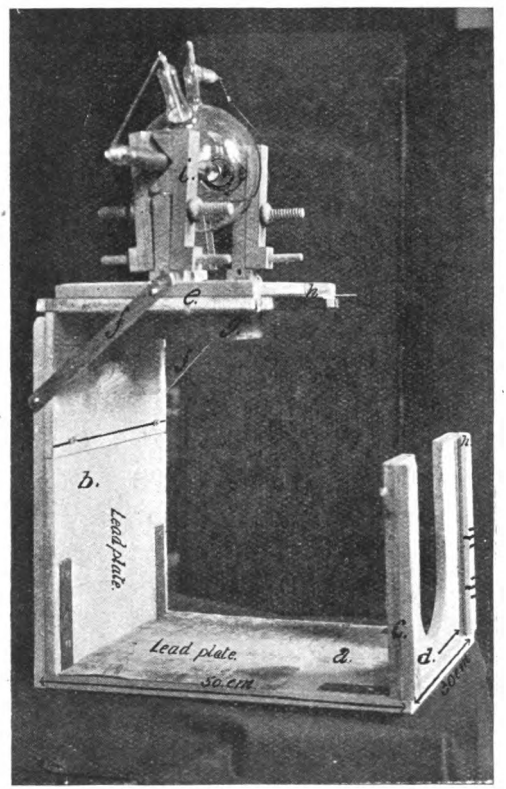


Illustration 9.
The tube is in position for antero-posterior plating; it easily slides out and into the lateral position.

body is desired to some bony landmark, this procedure can be used to advantage.

The tracings are drawn on celluloid, as previously described; the usual stereoscopic displacement of the tube is made

between the two tracings as for plates, very little work is required, a few bold outlines of the bony landmarks and the foreign body accurately drawn will suffice, and it is surprising, with a little practice, how easy they are to produce and what useful and accurate information can be obtained. (Illustration 8, fig. 5.)

Many still prefer the old method of plates at right angles, but it is fast being discarded, owing to the ambiguity involved when the foreign body is not in the same plane of projection on the two plates. To get satisfactory results by this method the normal ray should be centered through the foreign body in both directions, when the information given is reliable, although insufficient if the foreign body is not near some anatomical landmark, shown on the plate.

Reference to Illustration 9 will show a simple antero-posterior and lateral tube carrier (designed by the author) that insures the same projection. It is extremely useful.

Observations on Foreign Bodies.

In making the first observations on foreign bodies, much expense and time can be saved by having a number of sheets of celluloid cut to a size which will drop into the frame of the fluorescent screen. Upon these celluloid sheets the position of foreign bodies may be traced with a grease (or glass) pencil. These celluloid tracings may afterwards be retraced on to paper. In this way a great economy of plates may be effected, and, in most cases, an equal amount of information obtained.

Tracings with the Cryptoscope.

These can easily be made by placing the sheet of paper on a thin flat board and using a pencil, all but the point of which is enclosed in a metal holder; by approaching the cryptoscope as close as possible to the patient the enlargement of the image is reduced to a minimum, while care in preserving its horizontal position secures a projection free from distortion. (Illustration 10.)

Care should be taken to work with a small diaphragm, and

the hands should never be allowed to come into the fluorescent area; good gloves and full protection are imperative, and should be practised only when the exigencies of the service demand it.

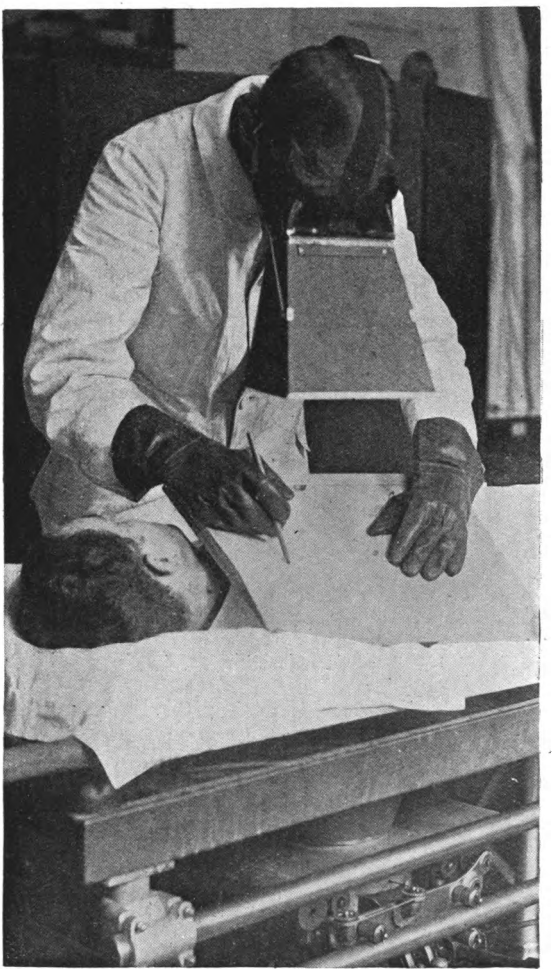


Illustration 10.

Making tracings with the cryptoscope. For the clearness of the illustration the cryptoscope is not brought near the tracing.

The Use of Bromide Paper.

The economy offered by bromide paper is most important

in war, particularly in view of the comparatively large quantity that one can transport. It is quite possible to make very good radiographs with rapid bromide paper, if an intensification screen can be used. Seventy-five per cent. at least of the graphs of foreign bodies can be taken on paper. Bromide prints made in this way are particularly useful, when only one copy is required to accompany a patient evacuated to another hospital. (See Appendix II.)

Pierced Screen Localisation.*

This method is very useful, exact, and of extreme simplicity. It requires a small fluorescent screen, pierced with a hole in

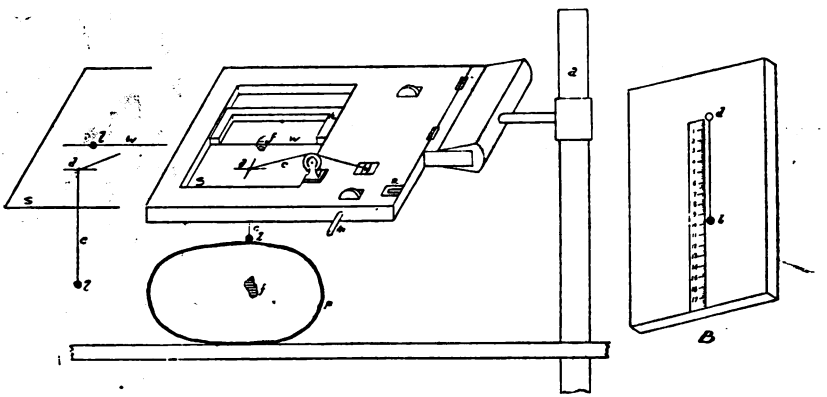


Illustration II.

its centre (Illustration II), intersected by a cross (*d*) to aid the centering of the foreign body. Through this perforation passes a thin cord, to which is attached a small lead pellet This cord can be let out or shortened by the shaft (*m*) on which it is wound. *h* is a travelling bar supporting a wire (*w*). The whole is held horizontally over the patient by attachment to the upright (*a*), and is hinged as indicated in the illustration.

In use the foreign body is carefully centered under the cross, and the skin is marked through the aperture by a small stick dipped in ink, the lead pellet is now removed from the

* Hirtz (Gaiffe, Paris), *Arch. de Méd.*, 1916.

small receptacle *n*, and sufficient cord released to allow it to just touch the skin, as *c*, 1; the apparatus may now be turned up (Fig. *B*); on its underside is fixed a measure, against which the distance from screen to patient is read off; this is noted, and the board is again lowered. The tube is now displaced any distance at right angles to the sliding wire *w*, which is then adjusted to bisect the displaced shadow of the foreign body (*f*). The patient's limb is now moved aside, the tube operated again, and the lead pellet lowered until its shadow is bisected by the wire *w*, as was the shadow of the foreign body; the pellet now occupies in space the position recently occupied by the foreign body in the limb; it now simply remains to lift the apparatus again on its hinges and read off the depth of the foreign body. Subtracting the distance previously measured from screen to patient gives the depth of the foreign body below the mark on the skin.

GEOMETRICAL LOCALISATIONS.

Localisation by Triangulation.

Originated by Sir James Mackenzie Davidson, this method forms the basis of most of the numerous localising appliances. It is very simple, and in the hands of careful workers is very exact. When used in detail as stipulated, with the cross thread localiser, it is probably the only method applicable to tiny foreign bodies that cannot be seen on the screen, or are in inaccessible situations, such as those embedded in the eye.

Briefly stated, the process is as follows (Illustration 12, Fig. 1). Centre the tube carefully under the foreign body with the diaphragm well closed down, and mark the position of the shadow on the screen (if it is large, mark one corner). Now mark on the patient's skin a dot corresponding to this shadow, and it is obvious that the foreign body is situated vertically below this mark, and an incision carried sufficiently deep must reach the foreign body. To find at what depth, the diaphragm should be opened wider and the tube displaced a known distance (say 10 cm.), and the shadow of the foreign

body will be displaced in the opposite direction; now mark, in its new position, the identical corner of the foreign body previously marked. With a pair of dividers, carefully measure this distance (*bd*), and write it down, with the distance (*ac*) that the tube was displaced. The only further measurement required is the distance from screen to anticathode (*ab*).

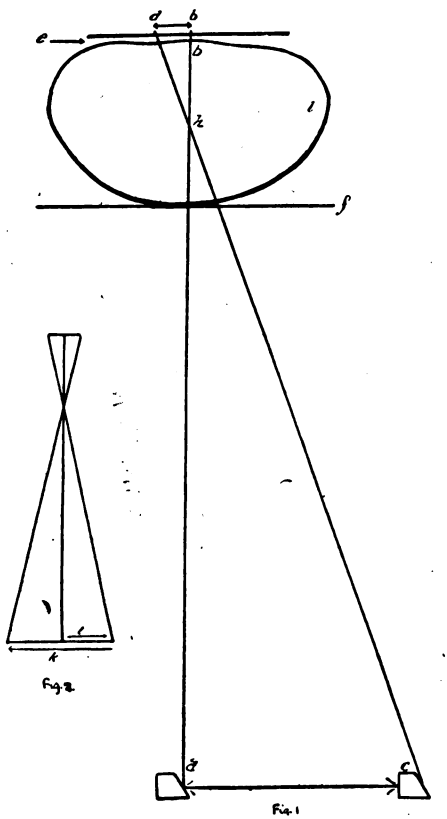


Illustration 12.

With these factors known, the depth of the foreign body below the screen is found by multiplying *ab* by *bd*, and dividing by the sum of *ac* and *bd*. From the results should be subtracted any space between the patient's skin and the screen. The linear path of the rays can be constructed

geometrically on paper if preferred, using a hard pencil with a sharp point, so that the lines may be as fine as possible and not obscure the intersection. Many forms of mechanical apparatus, such as that shown in Illustration 13, have been constructed to do away with the necessity of calculations and drawings, and other sliding rules have been devised to give

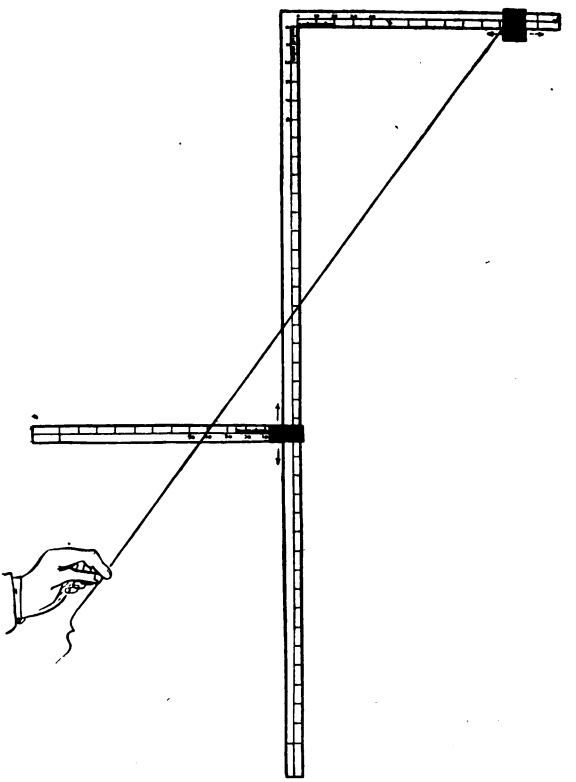


Illustration 13.

the depth, in reading on a scale, for a definite tube and screen distance and tube displacement.

When working by this principle it is as well to work to definite distances, such as 50 cm. from the tube to screen and 10 cm. tube displacement. It leads to accuracy, and mechanical attachments can be fitted to the table to enable the tube displacement to be made in the dark.

When desirable, stereoscopic plates can be taken, and a localisation made at the same time by replacing the screen by plates in contact with the patient, the only difference in technique being that the tube is displaced 3 cm. to the left of the central position for the first exposure, and 3 cm. to the right of the central position for the second (see Illustration 12, Fig. 2). In this manner the surgeon can avail himself of the anatomical localisation given by the stereoscopic plates at the time of operation.

Tiny Fragments.

Fragments too small to see on the screen, which yet must be removed, are best located by the complete Mackenzie Davidson technique.* The principle is as previously described, but as the foreign body cannot be centered, means must be resorted to to localise it wherever it may fall upon the plate. To accomplish this, the plate must first be tied up with wire as one would tie up a parcel, with the cross wires intersecting at the centre of the plate, or a frame or drum, with two wires affixed crossing at right angles, may be devised on which to place the plate. If an under-table tube is to be used, means must be provided to centre the anticathode immediately under the intersection of the wires; this can be accomplished by adjusting a plumb-bob to overhang the centre of the anticathode by an arm and scaffold that travels with the tube, or the cross wires may be placed upon the surface of the body and the tube centered by placing the screen on top. Whichever way it is accomplished, the skin must be marked with the same cross lines, and a small coin or metallic marker put in one quadrant and the same marked on the skin for identification later. The wires should be placed precisely, so that one crosses the long axis of the body horizontally and the other vertically, and the tube displacement should be made across the body. Two plates are now taken, the first with a displacement of the tube 3 cm. to the left and the second 3 cm. to the right of the centre, or one plate can be used with the double exposure on the same plate. When developed, the shadow of

* "Localisation by X-ray and Stereoscopy" (H. K. Lewis and Co., Ltd., London).

the foreign body will be found to have changed its position relative to the cross wires on the two plates taken, or two shadows will be found on the one plate. When dry, take a piece of transparent paper and place it on the plate, accurately mark in the cross lines, the impression of the foreign body,

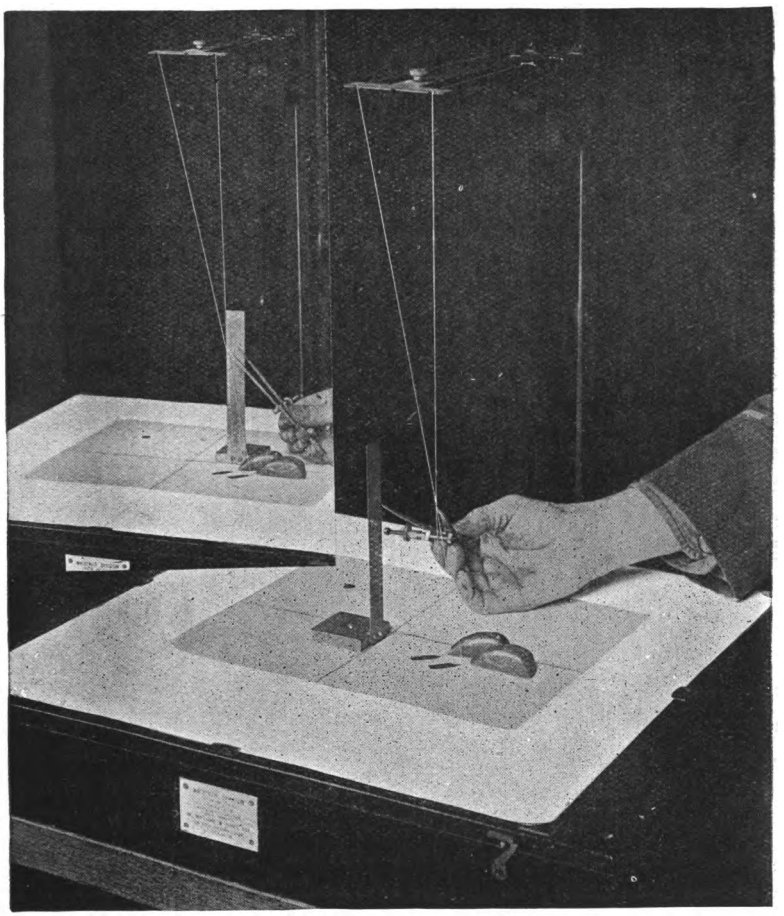


Illustration 14.

the indication of the marked quadrant, and the second shadow of the foreign body if one plate was used. If not, place the tracing on the second plate with the lines in register, and add the second shadow from that plate.

Armed with this tracing, go to the cross thread apparatus and place the tracing in register with the cross on the table of the apparatus (Illustration 14); adjust the height of the arm that carries the threads and indicates the two positions of the anticathode. Adjust this exactly to the height corresponding to the distance from anticathode to plate. From the notch to the left carry the thread to a chosen point of the foreign body traced on the paper to the right, and the right hand thread to the same point on the left. Where the lines cross is the position of the foreign body. Now take the indicator provided with the apparatus and adjust it to the height of the cross in the threads, and read off the depth of the foreign body on the vertical scale. Then place the vertical scale on the cross line of the table that forms one side of the quadrant in which the cross threads fall. Measure with dividers, at the level of the cross in the thread, the distance of this cross from the vertical scale. Repeat in respect to the second line of the quadrant. Now draw on the tracing, at the distances just ascertained, two lines parallel to those from which the measurements have been made. The intersection of these lines gives the point vertically below which, at the depth ascertained, the foreign body lies. The information is now complete. Now go to the patient, identify the quadrant, and mark in your data.

Additional Procedure Necessary for the Eye.

Before taking the plates for eye localisation a certain preparation of the patient is necessary. First, a few drops of novocaine may be dropped in the eye to allay irritation, if present. Then a small piece of fine lead fuse wire should be taken, bent double to avoid a sharp surface, and affixed to the cheek so that the folded end can be placed in contact with the lower eyelid vertically below the cornea. Notes must now be made of the exact position of this end, its distance below the centre of the cornea being observed from the frontal position, and its distance in front of or behind the centre of the cornea obtained from lateral observation. These measurements should be very accurately ascertained with dividers, as it is in relation to this identification point that localisation calculations are

made. It must be done when the patient is in the position in which the radiographs are to be taken, with the visual axis parallel to the horizontal wire.

To keep the gaze steady, while the plates are being taken, a bright object should be placed at a distance and exactly in front of the patient, at which he should look during both exposures. Lateral plates are taken, the cross wires being arranged with their intersection in front of and below the eye, so that the foreign body shall not be obscured by the wire. The tube must, of course, be carefully centered to the intersection of the wires. From plates so taken the relationship of the foreign body to the point of the lead wire can be absolutely determined, and the relationship of the lead wire to the cornea being known, the position of the foreign body in the eye can be definitely stated. The use of a model eye of a definite enlargement, and the necessary multiplication of the localisation figures, will help materially to decide the anatomical situation of the foreign body, and the possibility of its removal.

The same technique, if desirable, is practicable in anatomical localisation in other parts, employing any metallic indicator placed on the skin, or choosing a body landmark in the radiograph sufficiently distinct to be easily identified.

General observations on foreign bodies in the eye can be made by taking a small lateral plate, with two exposures on the same plate, one with the patient looking down, the other looking upwards. If the foreign body is in the eye itself, two shadows will be shown, unless it is situated in the axis of rotation; if it is in this axis there will be no duplication of the shadow. Otherwise, the position of the foreign body is shown by the movement of the shadow. If the movement is backwards and downwards, it lies in the posterior superior quadrant ; if downwards and forwards, in the posterior inferior quadrant; if upwards and forwards, in the anterior inferior quadrant; if upwards and backwards, in the anterior superior quadrant. An antero-posterior plate taken with a small fine wire cross, with its intersection central to the cornea will give additional information. This is a very specialised

branch of the work needing particular care, and should only be undertaken by those possessed of the necessary knowledge and experience.

Dr. Belot and Dr. Fraudet have developed the above method with a special technique that gives a very accurate localisation and necessitates very little additional apparatus. Their procedure is divided into two sections—exploration and precise localisation.

A lateral fluoroscopic examination is made first, and the whole area carefully studied with a very small diaphragm opening; foreign bodies may be found in other parts of the head and face, and by rotation of the head it is easy to decide roughly their position. This examination is necessary to prevent confusion, should there be more than one in the region.

The head is now placed in a lateral position for the examination of the eye in question. With the screen in contact with that side of the face, the tube is adjusted so that the normal ray shall pass through the orbital cavities; this position is easy to identify by the bright, almost oval patch appearing just posterior to the nasal bones.

If a foreign body is found here, it remains to determine whether it is in the globe; this can be ascertained by telling the patient to look up and then down. The movement of the foreign body may then be interpreted; if it moves in the same direction as the eye, it will be in the anterior hemisphere, and if against it, in the posterior hemisphere. Further differentiation will be necessary, because a foreign body in the muscles producing the movements of the eye will also be displaced; this will be dealt with later. Care should be taken to exclude the possibility of foreign bodies in the eyelids. Should the shadow of a foreign body be seen very anterior, and moving rapidly on the patient's opening and closing the eye, this location may be suspected. The parts may be individually immobilised during the screen examination; from such procedure a diagnosis can be formed. Much useful additional and corroborative information can be obtained by a supplementary antero-posterior examination.

For the exact localisation five radiographs are required, three lateral and two antero-posterior.

It is necessary for this method that the sight be preserved in one eye, and that the wounded eye shall have retained its mobility. It may then be assumed (should the injured eye not have retained sufficient sight) that the two eyes will make identical movements. The eye is regarded as a sphere whose

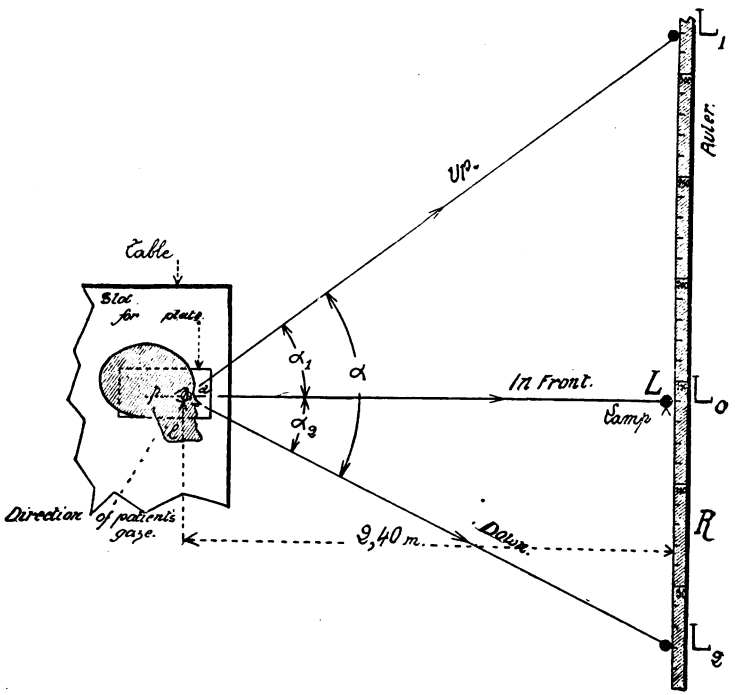


Illustration 15.

Position of the patient on the table with the rule and movable lamp to direct the gaze of the patient. Tunnel under which to slide the plate. *a* 1. The angle swept by the eye when looking up. *a* 2. The angle swept by the eye when looking down. *a.p.*, the cross wire over the plate.

movements are those of rotation about a centre which remains fixed; a foreign body in the eye will make movements definitely related to those of the eyeball. The comparison and study of successive radios, between which the eye has been rotated in a definite sense, will give data from which an exact localisation can be made.

If the foreign body rotates about the same axis and through the same angle as the eye, it is certainly in the eyeball, or in a part of the muscle. If the displacement is not a rotation about the same axis, a careful study will show if it is in the soft parts or in a muscle, and ultimately in which muscle it is situated.

For the production of the lateral radiographs, it is desirable to use a small table with a tunnel, so that the plates can be easily changed while the head is kept immobilised; quite small plates will suffice, say 9 by 12 cm. Across the opening under which the plate slides a fine wire is placed. The head is adjusted on

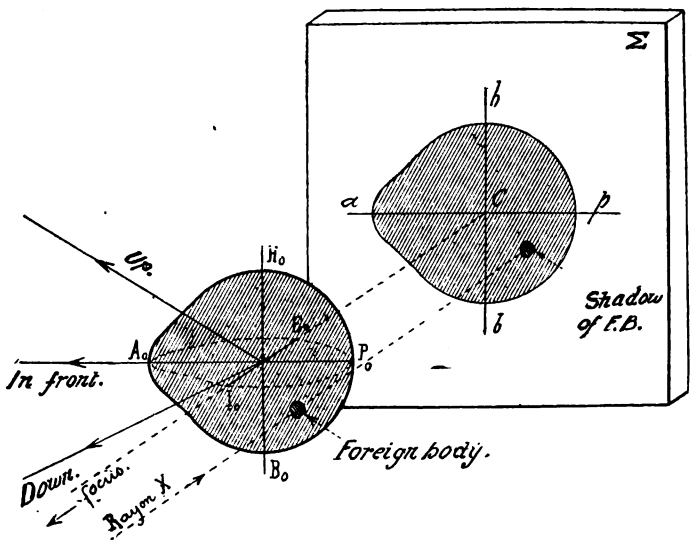


Illustration 16.
This illustration shows the relative positions of the eye and the plate in the production of the lateral radiographs. The axes are also shown. *a.p.*, the wire over the plate. Ao-Po, the corresponding axis.

the tunnel in such a manner that the metal wire is parallel to an imaginary line passing through the centre of the cornea and back through the central axis of the eye, while the patient gazes to the horizon, and that the shadow of the wire on the plates coincides with this line; thus the horizontal equator of the eye is materialised. (Illustration 15.)

The tube should be centered above at a sufficient distance to ensure that the resulting radiograph of the globe may be

considered an orthogonal projection. From a plate so obtained, measurements may be considered actual (for the lateral radiograph, 80 cm. from anticathode to plate gives a maximum error of 1 mm.; for the antero-posterior, 65 cm. gives the same error). The normal ray should pass through the central axis of the eye, and at right angles to the plate.

With the patient, tube, and plate so arranged, three radiographs are now made with the head immobilised; in the first plate (to be marked "*O*") the patient's gaze is directed to the horizon, in the second it is directed upwards, and in the third downwards, and the plates are marked accordingly.

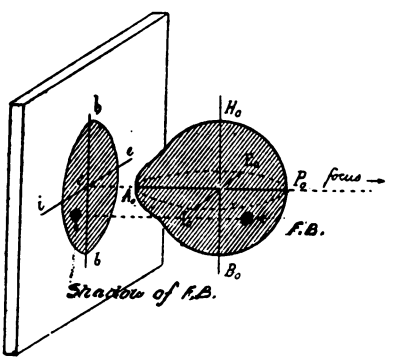


Illustration 17.
The relative positions of the eye and the plate are here shown for the production of the antero-posterior radiographs.
ie and *bb* **The cross wires in front of the eye and their corresponding axes are shown.**

For the antero-posterior radiographs two fine cross wires are required, and while the patient gazes to the horizon (or in this case vertically up to the ceiling), the frame carrying the cross wires is adjusted so that the intersection shall be vertically over the centre of the cornea, and the wires coincide with the horizontal and vertical equators of the eye; on these the plate is placed. The tube must now be centered so that the normal ray shall pass through the intersection of the cross wires. With the patient so disposed, and tube and plate arranged, the first plate is exposed, and for the second exposure the patient is directed to gaze to the side opposite to that of the injured eye (adduction). Five plates have now

been taken, and from the study of these the diagnosis will be made. (Illustrations 16, 17.)

The first step towards localisation is to make tracings from the radiographs—from each set one composite tracing is made. From plate "*O*" the outlines of the bony skeleton of the orbit and of the metal wire are drawn on transparent paper. The foreign body is also traced; this should be done accurately, with attention to any orientation it may possess; then carefully superimposing the tracings on the plates marked "up" and "down," the other shadows of the foreign body are added. The same procedure is followed in the production of the antero-posterior tracing. These tracings may be called "lateral" and "frontal." (Illustrations 18, 19.)

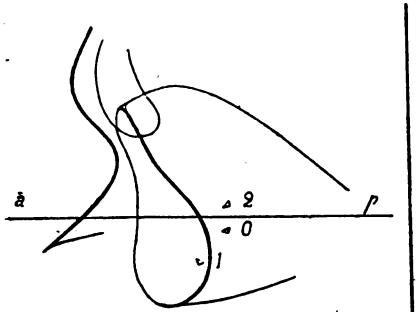


Illustration 18.
Lateral Tracing.

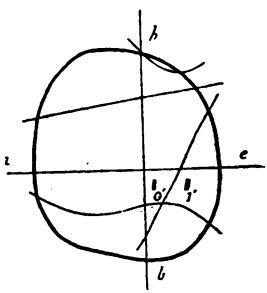


Illustration 19.
Frontal Tracing.

It is possible that the shadows of the foreign body may completely overlie; they may overlie in one tracing and be neatly separated in the other; or they may be separated in both.

A foreign body that has not moved in either is (*a*) not in the eye at all, or (*b*) in the centre of the eye; this latter possibility is important and must never be overlooked; it may mean a tiny foreign body located in the vitreous humour, or adhering to the posterior surface of the crystalline lens. If the foreign body is in the centre of the globe, its position in the lateral tracing will be slightly anterior to the shadow of the malar border of the orbit, and near also to the shadow of the wire that materialises the horizontal axis of the eye; and on the

frontal tracing it will coincide, or nearly so, with the centre of the cross wires. This question will only arise when the foreign body is very tiny and spherical in shape, otherwise it will be possible to follow its orientations in the changes of position.

Where the foreign body is on one of the axes of rotation, but not central, the shadow will have moved in one of the two tracings. (Illustration 20.)

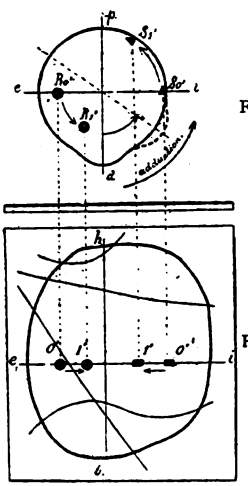


Fig. 1.

Fig. 2.

Illustration 20.

Foreign Body situated on the Horizontal Axis of the Eye.

Fig. 1. A horizontal section cut at the level of the centre of the eye when the eye looks to the horizon.

Fig. 2. Frontal tracing from two radiographs, between which the eye has moved in adduction; the tracing shows the movement of the foreign body in such a case.

Foreign body R in the temporal hemisphere during adduction moves forward from the position R 0 to the position R 1, that is to say it is displaced towards the centre.

Foreign body S, in the nasal hemisphere, is carried back towards the centre.

In the case in which the foreign body has moved and produced the three successive shadows on the lateral tracing, the process is as follows. Two fine lines are drawn connecting the three shadows (using the same point of orientation of the foreign body), and from the centres of these lines two perpendiculars are drawn; their intersection forms the centre of a circle passing through the three positions of the foreign body

(see Illustration 21). In this manner the centre of the globe is materialised. If this point falls just anterior to the malar border of the orbit, the foreign body is in the globe, and its position can be given in two directions, and the third obtained from the frontal tracing. If the intersection falls remote from the malar border, and from the horizontal plane projection, the foreign body is not in the globe but in one of the muscles. (See Illustrations 22-25.)

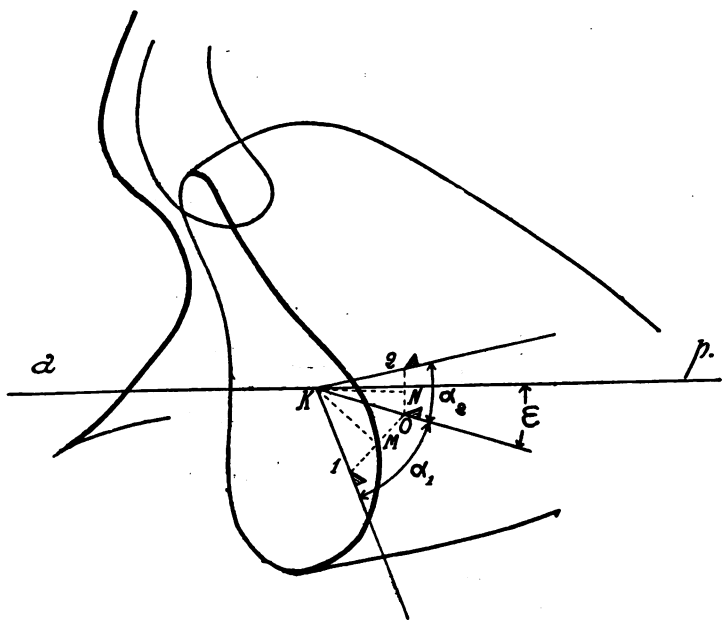


Illustration 21.
The geometrical construction on the lateral tracing foreign body in the eye.
Inferior posterior quarter.

To ascertain if the movement of the foreign body corresponds to the rotation of the eye, a long ruler, fitted with a movable electric lamp, is placed at a known distance from the patient and used to direct his gaze, and the displacements above and below the central or horizontal position are recorded. With this information (using cm. to represent metres) the angle the eye has turned through can be reconstructed on the lateral

tracing, showing definitely whether the foreign body has turned through the same angle. (Illustrations 15, 26-27-31.)

In those tracings which show that the foreign body has moved, and yet the centre of the circle on which the shadows

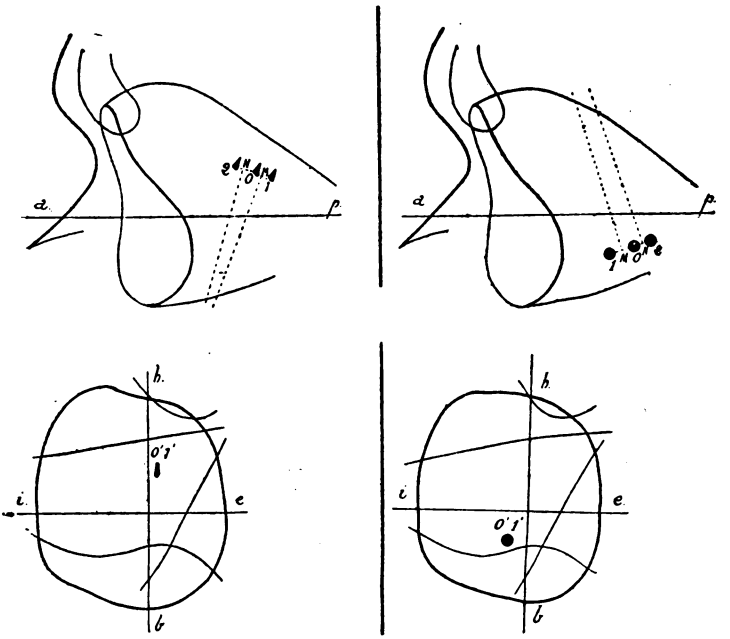


Illustration 22.

Lateral Tracing.

Foreign body in the superior rectus.

Fig. 1. The elevation of the eye produced by the contraction of the superior rectus muscle causes the foreign body to be pulled nearer to the fixed insertion of the muscle (Shadow 1).

When the eye is lowered the reverse takes place. The superior rectus is lengthened, displacing the shadow of the foreign body to the opposite side (shadow 2) of the zero position (shadow 0) which is the shadow formed when the patient gazed to the horizon.

The Frontal Tracing.

Fig. 2. The movement of adduction has hardly moved the foreign body; the two shadows overlie.

Illustration 23.

Foreign Body in the inferior rectus.

Lateral Tracing.

Fig. 1. In this case thelowering of the eye produced by the contraction of the inferior rectus draws the foreign body nearer to its fixed insertion (shadow 2), while the elevation of the eye by the contraction of the superior rectus lengthens the inferior and again displaces the foreign body to the opposite side (shadow 1) of zero.

Frontal Tracing.

Fig. 2. No movement is shown in the frontal radiograph; the shadows overlie.

lie does not occur at the point indicated as the centre of the globe, a little study will reveal the actual position of the foreign body; bearing in mind the muscles that produced the movements of the eye recorded on the plates, interpretation is comparatively simple. (Illustrations 22-25.)

Position of Patient.

In all methods of localisation, with one mark on the skin below which at a measured distance in the vertical line a foreign body is situated, all the general information of the

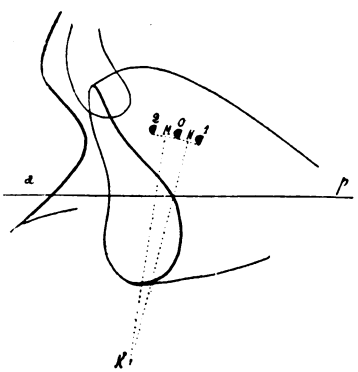


Illustration 24.
Lateral tracing with the geometrical construction showing a foreign body moving with the eye but not in the globe. The centre of rotation K is shown to be some distance away from the position known to be the centre of the eye.

previous examination should be studied. The patient should, if possible, be placed for the more exact localisation in such a position that, when he is operated upon, a vertical incision can be made through the localisation mark. If no satisfactory previous information is at hand, rough observations should be made, for it will frequently occur that the foreign body is not nearest to the surface at the point indicated, or important structures may intervene making it undesirable to operate through this point. It is, therefore, necessary to consider the position of the foreign body, and the best means of approach, and localise it with the patient so placed. It matters little if the incision has to be carried a little deeper along the localisa-

tion line, for one is fairly sure to strike the foreign body. But careful judgment is necessary to enter laterally for a foreign body localised in this manner, and the operation is often unsuccessful, the slightest deviation resulting in failure.

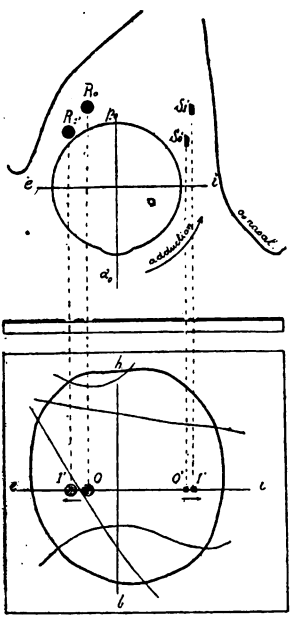


Fig. 1.

Fig. 2.

Illustration 25.

FOREIGN BODIES IN THE INTERNAL AND EXTERNAL RECTUS.

Fig. 1. Horizontal cross section at the level of the internal and external rectus. A.P. shows the antero-posterior axis.

Fig. 2. Frontal tracing (composite) showing the shadows of the foreign body produced by the movements of the eye.

RO foreign body in the external rectus. Plate taken with the patient gazing to the horizon gives the shadow O, formed by the foreign body when at RO. On adducting the eye the external rectus is lengthened and the foreign body moves to RI, placing the shadow on the radiograph at I, that is to say outward displacement.

SO foreign body in the internal rectus. Plate taken with the patient gazing to the horizon gives the shadow O′ formed by the foreign body when at SO. The second radiograph taken with the eye in adduction produced by the contraction of the internal rectus draws the foreign body nearer to the fixed insertion of the muscle SI, giving the shadow I′.

ANATOMICAL LOCALISATION.

While geometrical localisations are absolutely necessary, much more information is desirable to ensure the successful

removal of foreign bodies. It is never easy, in fact, rarely possible, to state the exact position of a projectile from flat plates. Antero-posterior and lateral radiographs at right angle planes and of the same projection are useful, and, at times, desirable, but they are a poor substitute for stereoscopic plates. From the latter the most valuable information can be obtained.

In the limbs, rotation and observations from several aspects may demonstrate whether the foreign body is in soft tissues or embedded in bone; but at an articulation, tarsus, carpus, shoulder, or vertebræ, every available device, manipulation, and the use of discriminating judgment will often be necessary

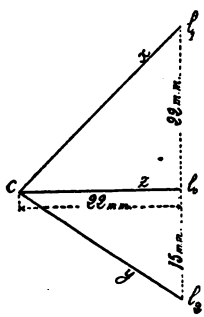


Illustration 26.
Reproduction of the angle of rotation of the eye on a millimetre to the centimetre scale.

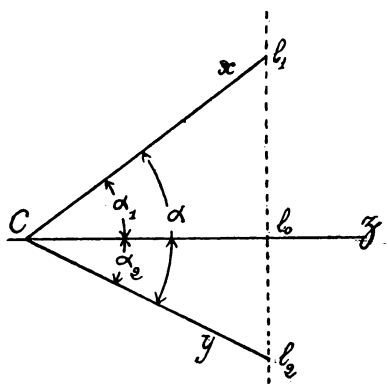


Illustration 27.
Geometrical construction of the angle of rotation of the eye.

in order to come to a definite conclusion. Besides turning the limb or body, use should be made of the oblique rays, by long displacement of the tube, in the hope of being able to throw the shadow free from bony structures.

It is even more difficult to decide the location of a foreign body in the thorax, abdomen, or pelvis. A projectile in the lung may move with respiration or not, depending upon its location; at the root there would be little if any movement, while at the base the excursion may be considerable. However, it must not be forgotten that a foreign body may be prevented from moving and yet be in a lung restricted by adhesions.

On the other hand, the moving shadow of the ribs may impart to the foreign body an apparent movement it does not possess. Further, the presence of air or fluid in the pleural cavity will complicate matters, and with a projectile fairly superficial in the lung it may be impossible to make a definite statement in a few cases. Frequently, an abscess forms about the foreign body, and later a cavity containing air, fluid, or

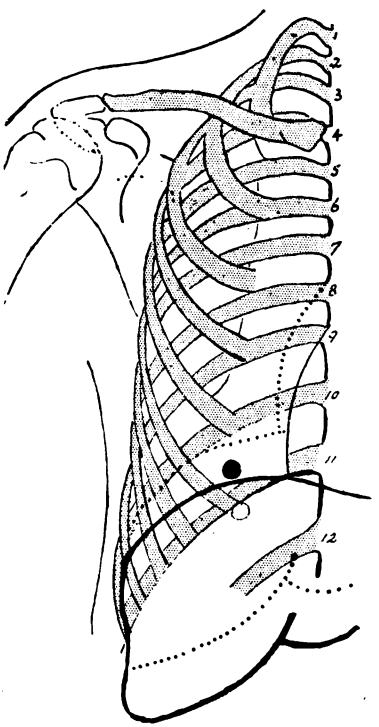


Illustration 28.
Dotted line of the diaphragm, normal respiration—dotted foreign body in the liver shadow: dark line of diaphragm, forced inspiration—dark foreign body projected above liver region.

both, and the projectile may be shown to be free in some cases by changing the position of the patient and allowing some time to elapse between observations.

Not infrequently, a projectile may be near or attached to a large vessel, and a "kick" may be observed imparted by the

pulsation, or such a movement may be communicated by the heart; in this latter case, the excursion of the foreign body will be greater, and may be seen to occur in the mediastinum and over a large area of the left lung, but may be somewhat modified if the lung is partially collapsed or consolidated in the vicinity.

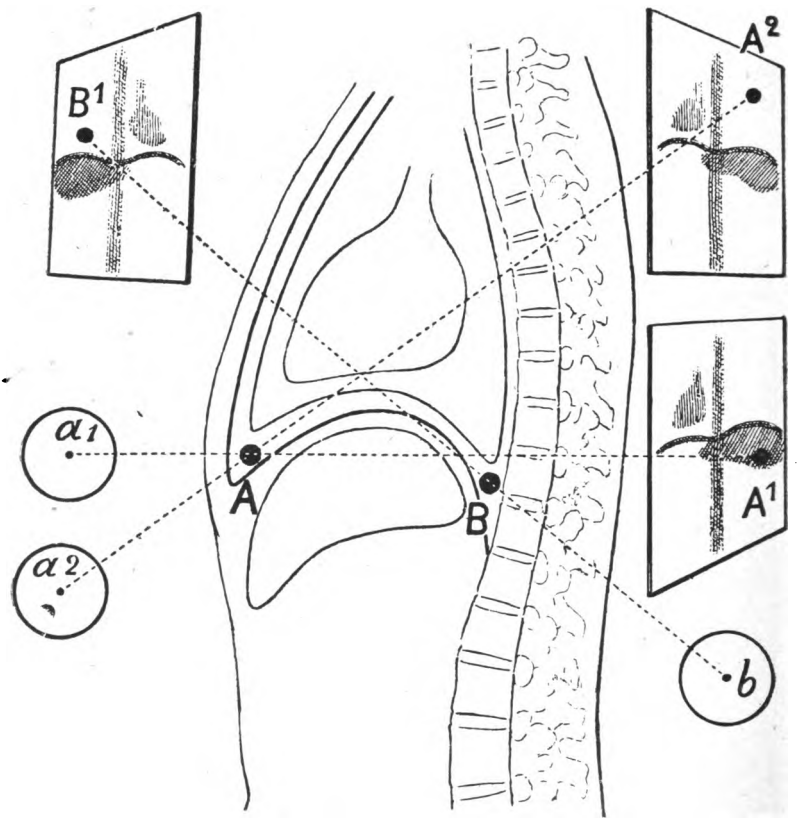


Illustration 29.
The circles indicate the positions of the X-ray tube with the corresponding projections on the screen when examining the region of the diaphragm.

These cases should all be submitted to thorough general observation, and all conditions noted and recorded with the localisation. Some help can be obtained by applying a small metal ring to the chest wall and observing the behaviour of the

foreign body in relation to this shadow. If the foreign body rises with inspiration and remains fixed in its relation to the ribs, it is most probably in or attached to the chest wall.

Attention to every detail is imperative, and statements should be made with the greatest caution, for upon these findings important and responsible decisions are to be made.

To decide the location of a projectile in the region of the diaphragm is particularly difficult. Forced inspiration will often show a foreign body to be above the diaphragm, when its shadow was projected well within the liver area with normal respiration (Illustration 28). The patient should be observed from every position. To search the posterior inferior portion of the chest the tube should be lowered posterior to the level of the fourth lumbar vertebra, when, by the oblique ray, the shadow may be thrown well above the diaphragm, settling all doubt as to its position. If this is not successful the position should be reversed. (Illustration 29.)

It is often impossible to give definitely the position of foreign bodies in the abdomen. They may move freely from time to time. For this reason observation on fresh cases should be made within a few hours of operation. Furthermore, it is not an unusual occurrence for a foreign body to be passed by the rectum, and should this occur a patient might be submitted to a needless operation. In cases where special difficulty exists, or an anatomical localisation is uncertain, preparation should be made at the time of operation for intermittent control by the fluorescent screen.

Stereoscopic Localisation.*

Undoubtedly, good stereoscopic plates give more information than antero-posterior and lateral plates, and in difficult cases they should always be taken, particularly if one of the stereoscopes for viewing and measuring the depth of the foreign body by a mechanical attachment is at hand, such as

* "La Radiostéréoscopie en Chirurgie de Guerre," *Jour. de Radiol. et d'El.*, March, 1916.

"La Localisation Anatomique des Projectiles par la Radiographie Stéréoscopique." *Loc. cit.*

the Mazo Radiostereometer* (Illustration 30), or the stéréothésmètre of Paris Richard. To this apparatus is fixed a small handle that controls the passage of a measure, and indicates on a dial the depth of the foreign body. The relation of the foreign body can also be determined to any

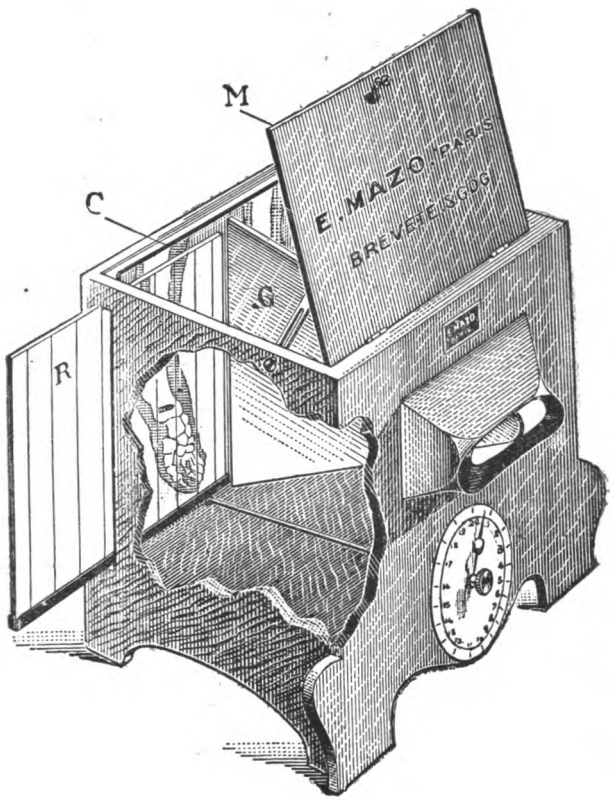


Illustration 30.

Stereoscope for measuring the depth of foreign bodies. C—X-ray plate, R—Movable register, G—Mirror bisector. On the front is the dial that indicates in millimetres the depth of the foreign body.

other structure shown on the plate. The calculations in this case are based on a distance from tube to plate of 50 cm. The first exposure is made from the central position, and the second with a lateral displacement of 4 cm., which measure-

* *Arch. d'Electricité Méd.*, Oct., 1917.

ment must be rigorously adhered to. The most portable and convenient form of stereoscope is the Binocular or Pierre form, or the Hirtz Mirror bisector type.

A simple appliance on this principle, devised by the author,* makes it possible to exercise considerable economy in stereo-radiography of the limbs, and no complicated apparatus is required for viewing. A small metallic badge may be used

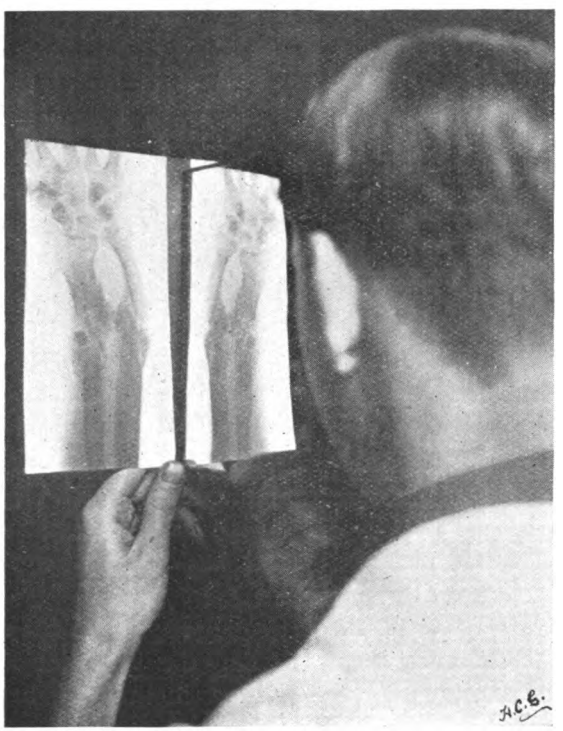


Illustration 31.
Stereoscopic realisation with a simple mirror.

to mark the sinus or wound, and a letter (the same one as that used for the purpose of marking "left" or "right") should be placed upon the anterior surface of the limb. A plate is now taken, half of which is placed under the limb in the usual position, with the film towards the tube, the other

* "Stereoscopic Radiography of the Limbs," *Arch. Radiol. and Electrotherapy*, June, 1917; *B.M.J.*, Sept. 29th, 1917.

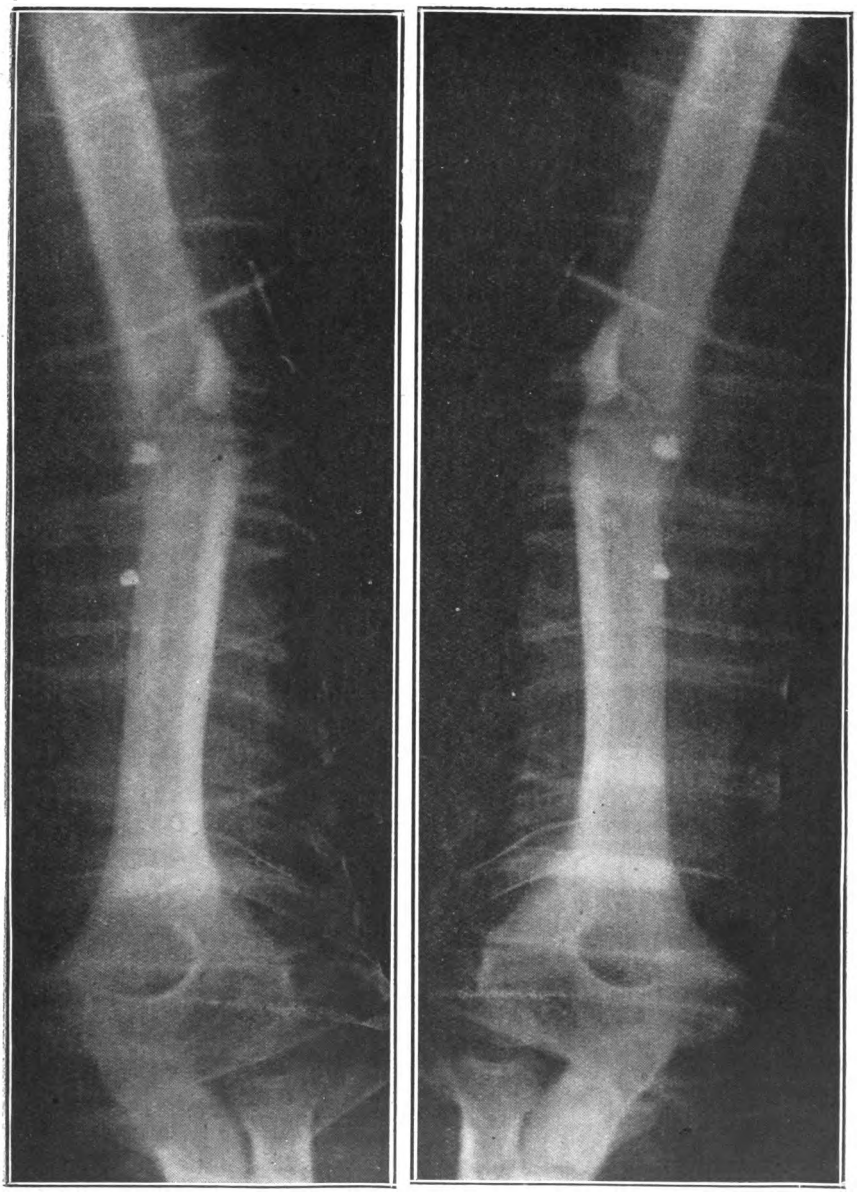
half of the plate being covered by sheet lead. The tube is centered over the limb, and afterwards displaced 3 cm. laterally. After the first exposure the plate is carefully withdrawn without disturbing the limb, and the unexposed half of the plate inserted, this time with the glass side towards the tube. The second exposure is then made after the tube has been again displaced 3 cm. on the opposite side of the centre. It will be found that the best stereoscopic results will be obtained by increasing the displacement for a thin limb, like forearm or hand, to as much as 4 cm. on either side of the centre; while for the thigh the displacement should be diminished. The height of the tube has also some influence upon the stereoscopic effect; the closer the tube is to the plate, the less displacement is required. To view these plates when so taken, all that is required is two mirrors, some 20 cm. by 25 cm. in size, placed back to back, and bound for convenience with a piece of adhesive tape (Illustration 31). The whole of the plate must be equally illuminated. The mirror should be placed in the centre of the two pictures, and the observer should close an eye until he sees one picture clearly reflected. When both eyes are open a stereoscopic projection is obtained. The position of the sinus (marked by the metal disc) becomes evident; and sequestra or foreign bodies, which might appear as one in an ordinary radiograph, will now stand out in relief, and can be enumerated, and accounted for at the subsequent operation. (Plate 1.)

Should the letter placed anteriorly appear on the side opposite to the observer, he is viewing the posterior aspect; to obtain the anterior aspect, he must incline the head to the opposite side and use the other mirror.

Cross Section Localisation by Three Intersecting Lines.*

The old method of localisation by two intersecting lines was not exact, and the method and technique to be described has been developed and perfected by the author. It is un-

* Belot et Fraudet, *Jour. de Radiol. et d'Electrothér.*, Jan., 1916.
J. M. Flint, *Ann. Surg.*, Aug., 1916.
H. C. Gage, *Arch. Radiol. and Electrother.*, June, 1917.



A typical stereo-radiograph which if viewed with a mirror will immediately illustrate the advantages of the method described. (The sinus in this case is marked with a pin.)

PLATE I.

doubtedly the one of choice where the foreign body can be seen on the screen. It is independent, as will be seen, of any mathematical calculations, it is accurate, and the results are self-proving, for the chart, when complete, discloses at once if the observations have been made correctly or not. The method in itself comprises geometrical and anatomical localisation

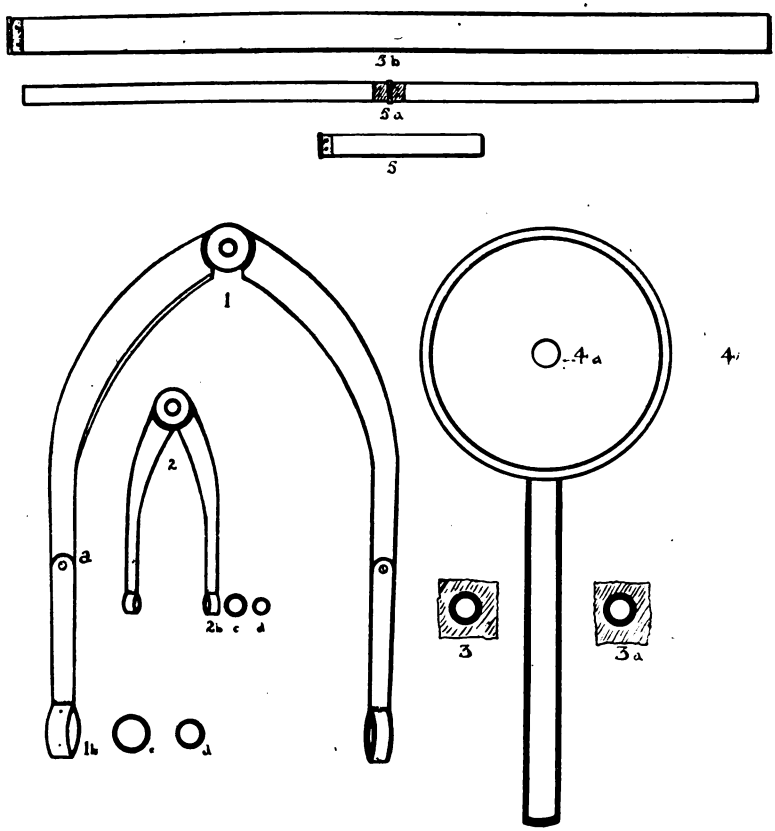


Illustration 32.
Localising appliances.

combined with mechanical guidance. The appliances necessary are very simple, and can, should the situation demand it, be home made. (Illustration 32.)

Two pairs of compasses are shaped as illustrated in Figs. 1 and 2. Two sizes are necessary, as it is desirable that the

rings shall be parallel when in use; a large pair (for the body) about 35 cm. long, a second pair (for the limbs) about 12·5 cm. The rings in each case can be made to enclose smaller rings to facilitate the centering of a tiny foreign body (Figs. 1 and 2, *b*, *c*, and *d*). The body compasses are further improved by jointing the last 6 or 7 cm. of the arms by means of a small bolt and thumb screw. (Fig. 1*a*.) With this additional adjustment the rings can be placed in contact with the body in any position.

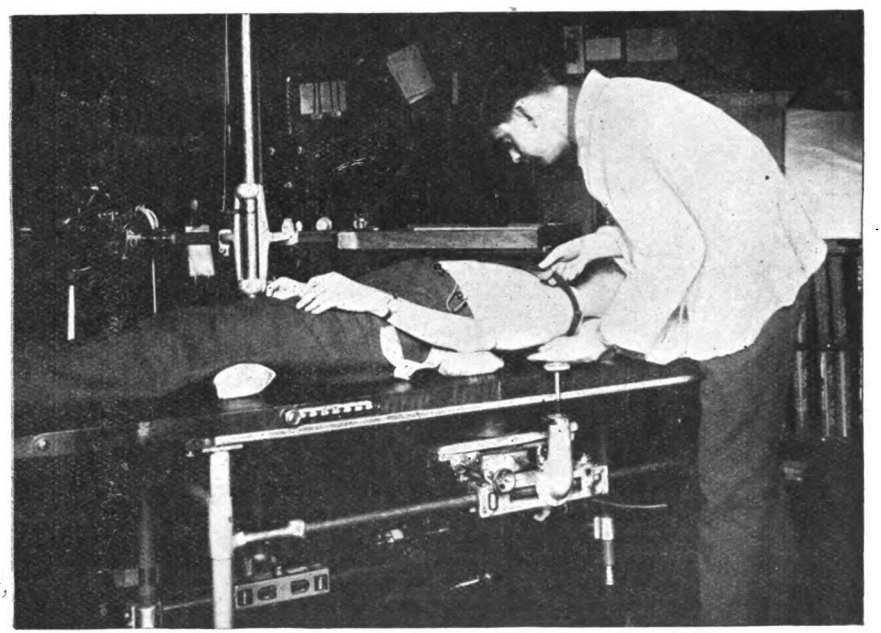


Illustration 33.
Antero-posterior observation.

In the first method the compasses are used in the following manner. The patient is first placed, if a horizontal table be used, upon his back. Long sandbags may be laid under the patient on either side of the area of localisation, in order to permit the insertion of the compasses beneath the limb or body. Other sandbags may be adjusted for the comfort of the patient. (Illustration 33.) Should a table with sliding cross panels be

in use, one of these panels may be removed to provide convenient access. Observations in the antero-posterior position are made, adjusting the compasses in such a manner that the foreign body appears on the screen encircled by the rings. (Illustration 34, Figs. 1 and 2.) The skin is marked through these rings with blue grease paint and the patient then rotated. In this rotation great care should be taken, for the accuracy of

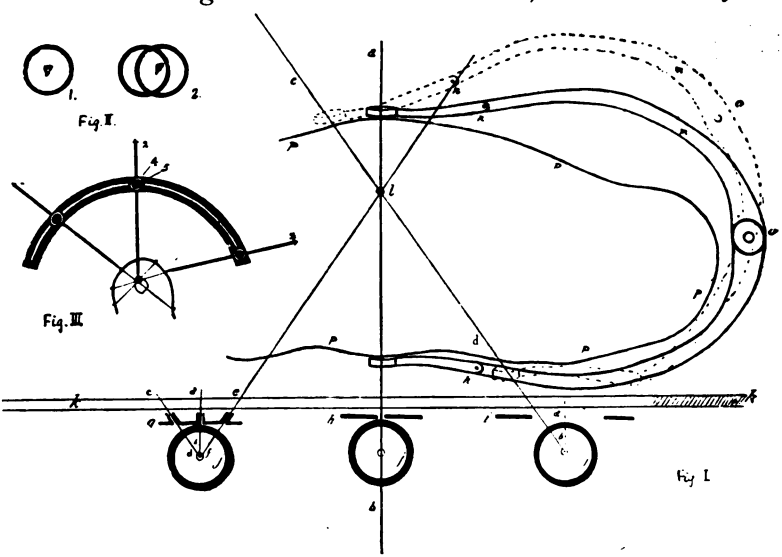


Illustration 34.

Diagrammatic Application of Compass, Diaphragm and Arc.

Fig. 1. *a*, *b*. Normal ray; *c*, *d*, *e*, *f*. Oblique rays; *g*. Diaphragm with tubes; *h*. Closed diaphragm; *i*. Open diaphragm; *j*. X-ray tube; *k*. Table; *l*. Foreign body; *m*. Compass; *n*. Additional hinges; *o*. Principal hinge; *p*. Patient.

Fig. 2. 1. Well centred; 2. Badly centred foreign body.

Fig. 3. Arc (for use at operation); 1 and 3. Probes (in position on localisation marks on skin); 2. Measured probe (in position on foreign body); 4. Nut; 5. Thumb-screw.

localisation depends upon the turning of the limb or the body, as one would turn a cylinder, so as to avoid change of contour of the surface anatomy. If such a change takes place a false relationship between the foreign body, and the superficial markings on the skin will result. With a little care, however, and in the case of the body, a vertical screening stand, this difficulty will not occur. Having successfully turned the

patient, the foreign body is again encircled with the rings of the compass and further skin markings made with grease paint of another colour. This marking is then repeated in a third position, making three observations in all, and giving six marks of three colours upon the skin.

Production of the Outline Contour.

Reference should now be made to Illustration 32, Fig. 5, 5*a*, and 5*b*—showing strips of soft malleable metal, which

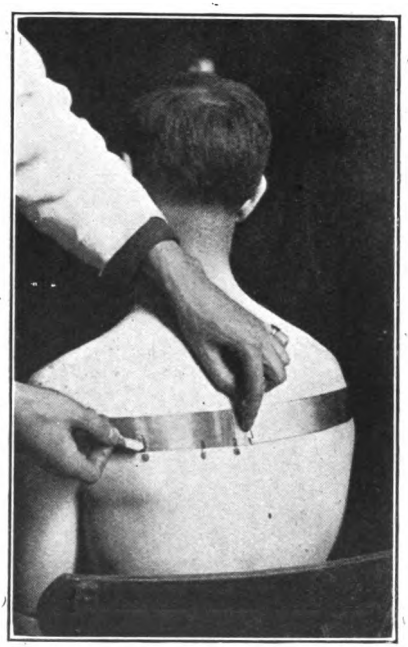


Illustration 35.
Taking the contour of the body and transferring the skin markings to the metal band.

can be obtained from any medical electrical warehouse. They are made of an alloy used for high frequency electrodes. The strips should be some 2 cm. wide for the limbs and 4 cm. wide for the body, and of various lengths, sufficient to encircle the different circumferences of limbs and body. They are hinged in the centre. When in use (Illustration 35) the

hinge should be placed upon some anatomical landmark to facilitate reference; the spinous process of a vertebra is very suitable for the purpose. "Right" or "left," and "anterior" or "posterior," should be marked upon the metal. Care must now be taken to mould the band to the exact contour of the body. Where the metal overlaps, a line is drawn on the band, also the positions of the coloured markings on the skin are transferred to the metal band, as well as the position of the wound of entrance or the incidence of the perpendicular

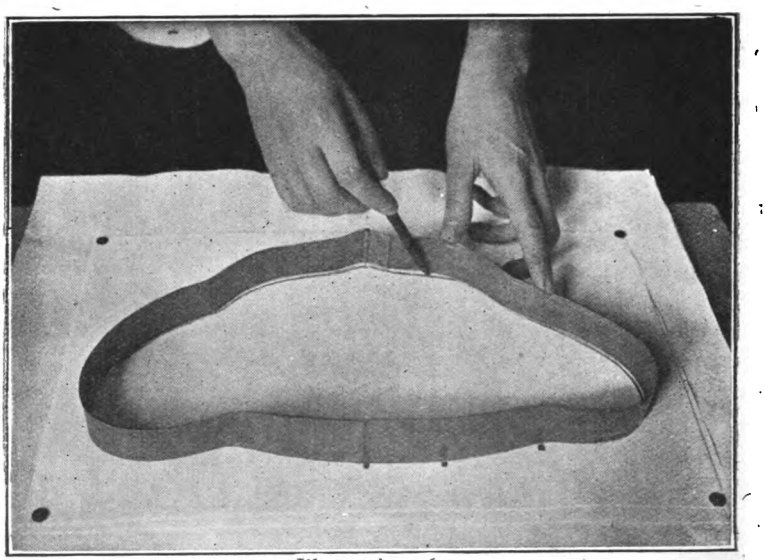


Illustration 36.
Transferring the contour (and markings) to paper.

drawn from it. The metal is then lifted, great care being taken to see that the contour is preserved, and placed upon a sheet of paper. The internal contour is traced with a pencil on to the paper, and the coloured marks are transferred. (Illustration 36.) The anatomical level of the foreign body should be noted, and, if the wound of entrance is not in the same plane, its distance superior or inferior measured. As an additional precaution, until the worker is familiar with the method, large wooden calipers may be used to take the lateral and antero-

posterior measurements of the body, in order to confirm the shape and position of the transferred metal. The coloured marks are connected with the aid of a ruler, and if care has been exercised it will be found that the three lines intersect within an area not larger than the foreign body. Should this not be the case it is obvious that some error in technique has been committed. If the observations have been correct, the intersection will represent the position of the foreign body. The grease paint marks upon the skin may be rendered permanent by nitrate of silver.

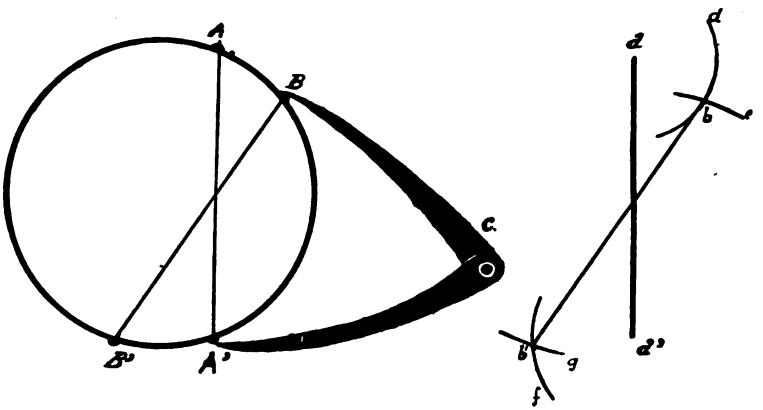


Illustration 37.
Geometrical Method of Debierne.

In the absence of metallic bands, recourse may be taken to a geometrical procedure to realise graphically the position of the foreign body, from two readings antero-posterior and oblique, taken as previously described.* Illustration 37 shows $A\ A^1$ an antero-posterior observation, $B\ B^1$ an oblique observation. To transfer to paper, the distance $A\ A^1$ is measured by a large pair of wooden compasses and a line drawn of this length, $a\ a^1$. Large ordinary compasses are now taken, and with the distance $A\ B$ as radius, with a for centre, the arc d is described; then with the distance $B\ A^1$ as radius, and a^1 as centre, the arc e^1 is described; the distance $A^1\ B^1$ is now taken for radius, with a^1

* Debierne. *Presse Méd.*, No. 9, March, 1915.

as centre, and the arc f^1 described; and with the distance $A\ B^1$ as radius, and a as centre, the arc g is described. The intersection of $a\ a^1$ by the line $b\ b^1$ joining the intersections of the two pairs of arcs gives the position of the foreign body with regard to the marks made, but does not give the distance from the skin at any point between these marks, and therefore is not nearly so practical and helpful as the metal band method.

Modifications of Technique.

Before passing on to the amplification of the chart, which gives the anatomical location of the foreign body, some modifications may be suggested which may be preferred by some workers. In the absence of compasses, if desired, small rings like those shown in Illustration 32, Fig. 3, 3*a*, can be used. These rings, which may be of various sizes and improvised from metal washers, are first placed on a disc of adhesive plaster, in the centre of which is a hole through which to mark the skin. Illustration 32 shows a small fluorescent screen, perforated in the middle (Fig. 4) to permit direct anterior marking without fixing a ring. This will be found a very useful alternative, as it saves time.

Another modification of the method, necessitating some additional apparatus, is as follows. An X-ray tube is so fixed that it can be brought near to the posterior surface of the patient. (It might here be noted that it is advisable, in this case, to protect the patient by a sheet of aluminium.) A long displacement of the tube must be possible in the direction across the patient. The tube having been well centered, and the diaphragm closed down upon the foreign body, the antero-posterior position is marked through the compasses or small metal rings, as already described. The tube may now be displaced as far as possible, and the diaphragm opened to include the foreign body, which is again encircled with the metallic rings and marked; the observation is then repeated in the opposite direction. To be able to work this method and to get a sufficient angulation, it will be found necessary to have the anticathode within 10 or 12 inches of the patient. The time occupied in making these

observations is so short, however, that with an aluminium filter there is no risk of burns if rays of a hard type are used. A big advantage of this modification is that the observations, providing the tube has been accurately centered, will always be in the same plane without the slightest deviation. The proceeding with the metal band is identical with that already described. Some difficulty may be found in getting a sufficient displacement of the tube. Reference to Illustration

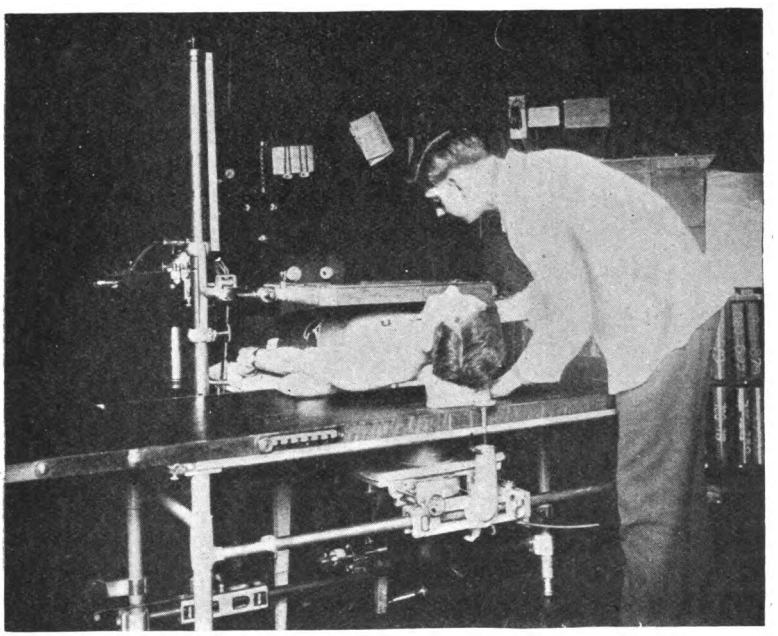


Illustration 38.
Tube displacement method with extemporised bench at right angles to X-ray table to secure the long displacement across the patient (central position).

38 will show a means whereby it is possible to extemporise with a small bench placed at right angles to the X-ray table, or removable flaps may be adjusted to the latter.

Chart Production from Localisation by Triangulation.

If it is desirable to use the triangulation method of localisation, in the case of a very sick patient, or by choice of the

operator, the tube may be centered under the foreign body, and the anterior and posterior marks placed upon the skin, after which a plate is placed over the anterior mark and an exposure made. The tube is then displaced to a known distance and a second exposure made. A diagram can be made for the purpose of calculating the depth of the foreign body on the line of the normal ray, using the method previously described (Illustration 12). The contour of the body, at the level of the markings, should now be taken and transferred to a sheet of paper, with the antero-posterior markings; these are connected by a line, and the calculated position of the foreign body recorded. Other marks may now be placed upon the outlined contour, in such a manner that lines drawn through them will intersect at the position of the foreign body; the marks are then transferred to the skin by replacing the malleable metal band. In this way choice of entrance, with fixing points for mechanical guidance, will be available at the operation, and the advantage of a cross section anatomy utilised.

Anatomical Localisation by Amplification of the Chart.

Whichever method may have been chosen for the production of the skin markings, the procedure for transferring them and the contour of the limbs or body on to paper is the same, and the same intersecting lines are drawn. The cross section anatomical details of the area at the level of the foreign body may then be filled in. Reference to Illustration 39 will show in what manner these graphic amplifications may be made. A line may also be drawn showing the path of the projectile, and the chart will thus disclose, not only the anatomical situation of the foreign body, but also the route it has taken to reach its position, as well as any vessels or organs which may have been injured in its transit. In the event of the wound being somewhat remote, other cross section diagrams at intervals will be of considerable help, or, if a sagittal section of the area is available, work may be saved by referring to it.

An example of such a reconstruction of the wound track,

in successive sections, is shown in the frontispiece. In this case the wound of entrance was between the seventh and eighth ribs, at the level of Section 27 in Eyclesheymer and Schoemaker's Atlas, while the foreign body was localised between Sections 31 and 32, and the intermediate sections are shown, with the path of the projectile reconstructed. The sections are traced from the atlas on ordinary tracing paper, and the reconstruction is carried out with the help of a scale diagram, as shown in Fig. 1. The width of the patient is measured at the level of the foreign body, and the width of the atlas section at the same level is also measured. The localisation has already given the lateral distance to which the

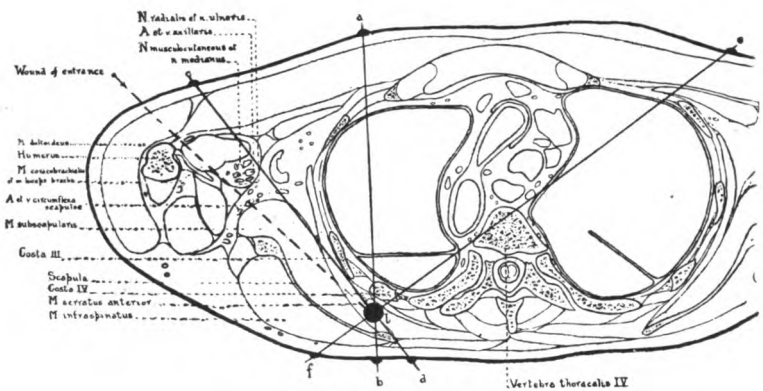


Illustration 39.
The anatomical amplification of the chart.

foreign body has penetrated, and the corresponding distance on the scale of the chart is worked out from the two measurements just made by simple proportion. These two distances can be marked off along a horizontal straight line, as *OA* and *OB* in the figure. A second line, *OC*, is then drawn at right angles to this, along which the distances separating the required sections of the chart can be measured off. Thus, in the case shown, the foreign body was localised 10 mm. below Section 31; 26 mm. separate Sections 30 and 31, etc. From the points so marked along the vertical, horizontal lines are drawn parallel to *OA*, and a straight line *CB* is drawn cutting these. Since

the wound of entrance is at Section 27, and the foreign body at a point represented by *B*, between Sections 31 and 32, the lengths cut off by *CB* along the horizontal lines represent the depths to which the foreign body has penetrated at each level, on the scale of the chart. All that is now needed is to rule on tracing paper a line of the length *OB*, and placing it in turn over the horizontal lines of the chart, prick through with a pin the successive distances of penetration. The positions of the wound of entrance and of the foreign body are marked on the first and last sections respectively; then all the sections are superposed, with the straight line arranged over them so as to run from the wound to the foreign body. The pin holes are pricked through, and the appropriate points on each section being joined by a thick straight line, we have the path of the projectile through each region of the body, and it is at once evident what organs are probably involved. The subsequent history of this patient showed that all the organs through which the wound track passes in the charts were actually injured, except the aorta, which was evidently just missed.

With charts constructed in this way the surgeon has definite information as to the exact position of the foreign body, with full confidence in the absolute accuracy of its localisation. He also knows the position of organs or vessels of surgical importance, near or distant, and by a glance at this chart the easiest approach for removal of the foreign body is at once obvious. If it has been observed in the radiograph that a bone, not in the direct course from wound to projectile, has been injured, the path of the projectile would be from wound to injury and from bone injury to localisation. This chart, when so prepared in conjunction with a report of the general findings, provides the surgeon with the most valuable document possible, and one in which he can have the utmost confidence, and attached to the history of the patient it forms a permanent record. This is particularly desirable should it be deemed inadvisable to operate. A copy accompanying the patient's evacuation papers will safeguard the patient and obviate further observation at another hospital, or constitute in the most acceptable form the information necessary for a decision to be

made by a Medical Board. Transparent paper can, of course, be used in the preparation of these diagrams, so that if desired, they can be superimposed on a cross section atlas and the anatomical details traced in. Eyclesheymer and Schoemaker's Atlas is very suitable for this purpose. Such an atlas should be available in every department.

Localisation of Foreign Bodies in the Head.

Additional precautions are necessary for the localisation of a foreign body in the head. An exact localisation can be made by using a length of wire to embrace the circumference of the head, and fixing it so as to mark out a horizontal plane passing through the two marks of the first observation. It is then possible, during the subsequent fluoroscopic observations

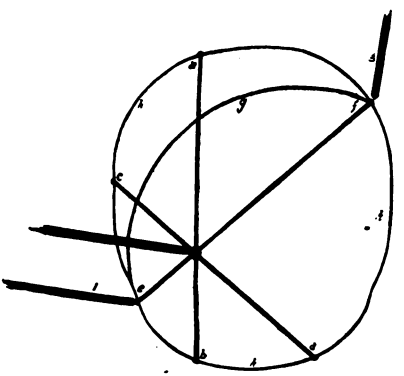


Illustration 40.
Localisation chart of the head, showing the contour of the dome *g* added to the localisation line *e f*.

to turn the head in such a manner as to maintain the same plane, and to adjust the position so that the wire intersects the shadow of the foreign body as a line and does not appear on each side as an ellipse. (This same technique may be applied with profit when making localisations with the open diaphragm, as in the first method, p. 42.) In other respects the procedure is the same as that already described.

Further localisation observations for foreign bodies in the head can be made by means of the strip of soft metal used for

transferring contours. (Illustration 32, Fig. 5.) To give additional information as to the position of the foreign body in relation to the vault, the metal should be placed so as to take the contour of the dome of the head vertically over any pair of localisation marks (Illustration 40, *ab*, *dd*, or, as here shown, *ef*.) The points chosen should be those best suited to whatever sagittal sections one may have at hand. This contour can then be added to the same localisation line on the chart, so that we now have the foreign body localised in a vertical

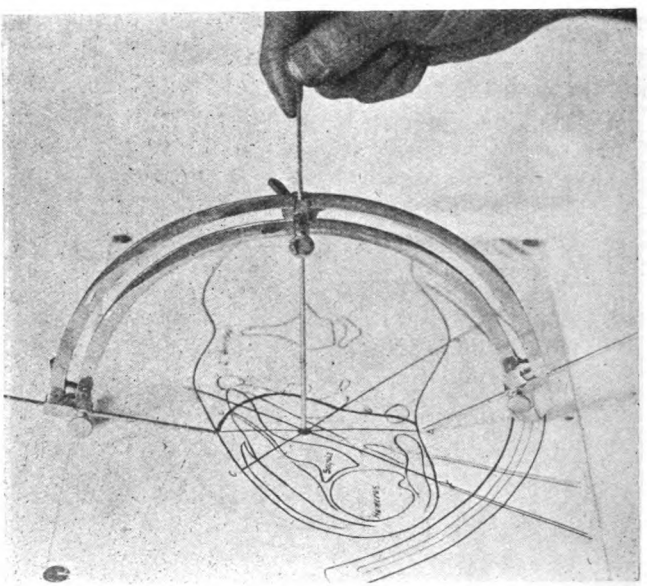
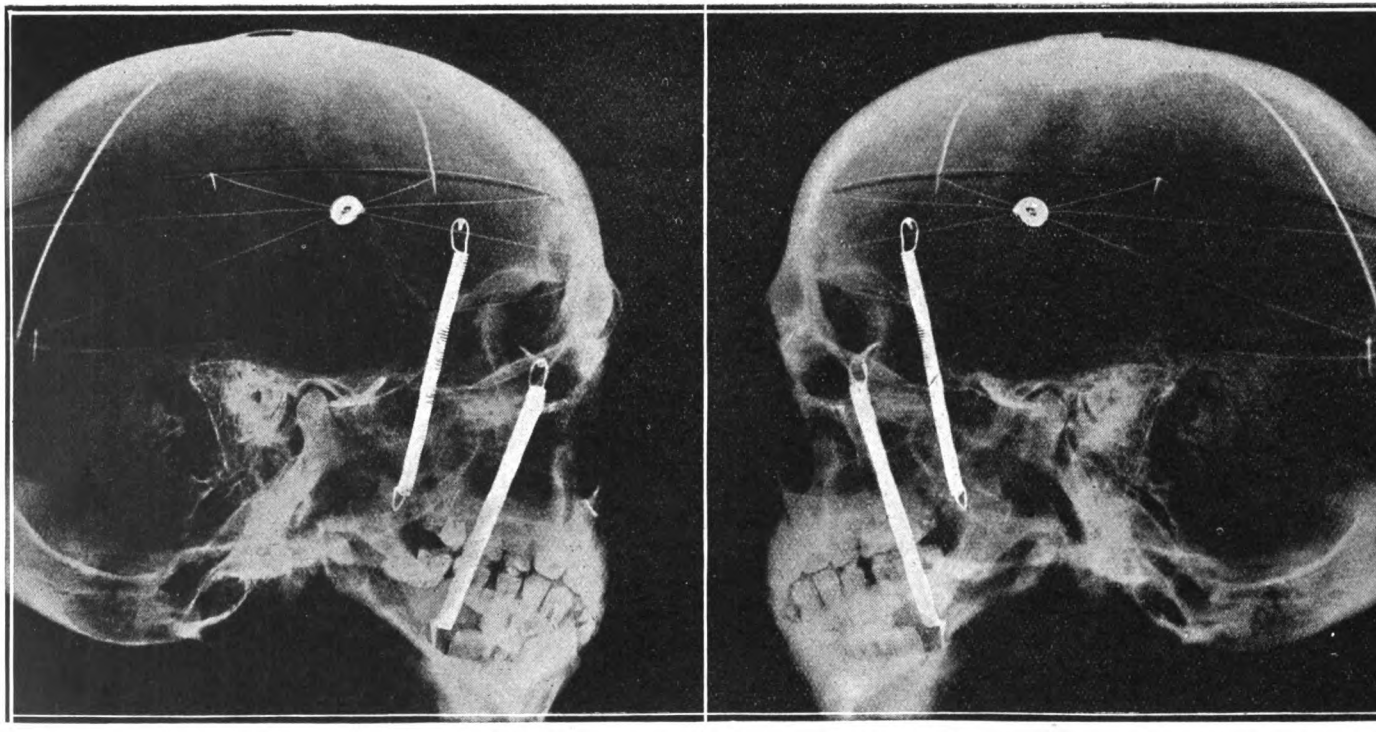


Illustration 41.

Chart of a foreign body localised at the level of the second dorsal vertebra—access is impossible posteriorly; therefore the contour is taken vertically over the shoul ler from the antero-posterior observation and the arc adjusted as illustrated.

plane also, and its distance can be measured from any point of the vault in this plane. A line drawn from the foreign body, either to the part of the skull through which the surgeon wishes to trephine, or to the wound of entrance, gives the required direction for the mechanical guide described below. If a localisation observation does not intersect the wound, or the



This stereo-radiograph should be viewed by the application of a mirror as suggested, when it will be found to help very considerably in elucidating the method of localising foreign bodies in the head.

PLATE II.

most practical point of entrance, an additional observation can be made for the purpose in such a direction that a vertical plane through it will include both the foreign body and the required point. A small metal disc placed over this point will render it visible on the fluorescent screen, and thus enable the required direction to be accurately determined. It will thus be seen that by means of this fourth observation the foreign body may be reached definitely through any desired point or previous opening. When a localisation is not required to one particular point, the shortest line of approach from the vault to the foreign body is obvious from the chart, and this gives the point of entrance, which can be marked on the scalp by replacing the metal band. This same technique can be applied with profit to the shoulder and other parts of the anatomy. (Illustration 41 and Plate 2..)

Mechanical Guidance.

Several forms of apparatus for supplying such guidance have been devised. A simple and convenient one is the arc shown in Illustration 34, Fig. III. It is made of metal, and is constructed to take three movable fittings, each being bored for the passage of a probe. These fittings, which are in the form of composite nuts (Fig. III, 4), can be firmly fixed in any position on the arc, while the probes (1, 2, and 3) are still left perfectly independent and free to be fixed, in any position, by a separate thumb screw (Fig. III, 5) fitted in the nut. One of the probes (2) is marked in millimetres. To use the arc, it is laid flat on the localisation diagram; the measured probe is placed on the point corresponding to that chosen by the surgeon for his incision, and directed towards the foreign body, and the points of the other two probes are placed on any other two localisation marks within reach. The nuts and screws of the latter are now firmly fixed, the nut alone of the measured probe is made secure, and this probe when pushed forwards must arrive at the position indicated as that of the foreign body. Notice is taken by the surgeon of the exact depth of the foreign body, as indicated on the diagram, then the measured probe will show the depth to which the incision

must be carried to reach it (Illustration 41). The arc is then sterilised. This simple apparatus can be placed on the marks in the field of operation, and as the incision is made the central probe will mechanically follow, until, at the depth previously ascertained, it touches the foreign body (Illustration 42).

It has been found possible, in suitable situations, to take a sharp pointed probe or cutting needle, and by inserting this

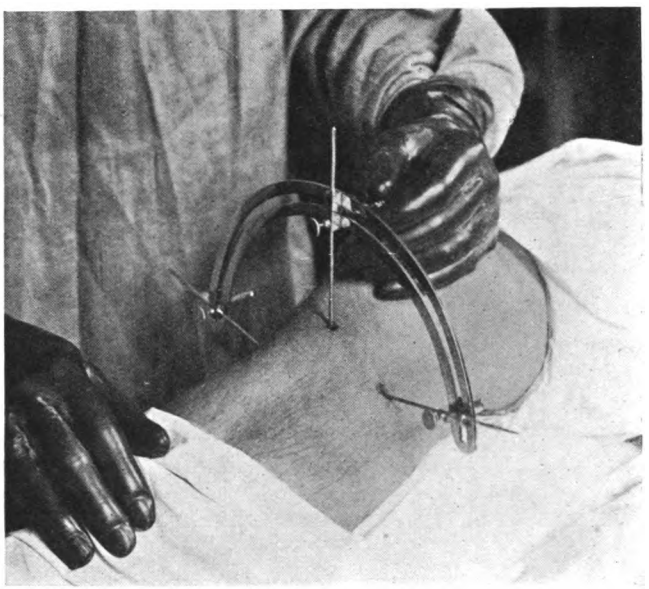


Illustration 42.
The arc in the field of operation.

along the line between the localising points, to push it home to strike the foreign body. Contact may be controlled by attaching the telephone probe described later. This makes extraction possible through the smallest incision.

Care should be taken in all circumstances to place the patient upon the operating table in the exact position he occupied when the markings were made. Although this is not so important as in most other methods of localisation, it is obvious, for instance, that a localisation made in pronation

would be invalidated should the operation be performed with the limb flexed or in supination.

Compass of Hirtz.*

While originally designed for use with a more intricate and tedious technique, this compass is nevertheless admirably adapted for use as a mechanical guide for removal of foreign bodies, and can be employed with almost any method of localisation when the foreign body is of known depth vertically below a given mark.

The compass will be seen in Illustration 43. It is placed upon the patient and the three legs regulated so that the point of the central indicator is on the localisation mark and is perpendicular (Fig 1); the legs should rest on bony structures when possible. The illustration shows an arc which can be attached so as to turn about the centre of the apparatus; the legs of the compass are then regulated so that the foreign body becomes the centre of the circle of which the arc is a segment. The arc rotates on its attachment in such a way that its centre remains unaltered; the probe can be attached to the arc by a sliding nut, which keeps it lying always along a radius, and therefore, as it moves round the arc, it is always directed at the position of the foreign body, and so gives a choice of position for the operative incision within a considerable range. (Fig. 2.)

Removal of Foreign Bodies under Fluorescent Screen.†

In every hospital serious consideration should be given to this method; it can be carried out in the operating theatre, in the X-ray department, or best in a room specially equipped and set apart for the purpose.

In any case it may not be necessary to duplicate the installation if the X-ray department is, as it should be, next to or not too remote from the operating theatre. The current for the

* A. Charlier, *Journal de Radiologie et d'Electrothérapie*, April, 1915.
E. Hirtz, *loc. cit.*, Jan., 1916.
Morin et H. Béclère, *loc. cit.*, Jan., 1916.
Morin, *loc. cit.*, Nov., 1916.

† "L'Extraction des Projectiles à l'Aide du Controle Intermittent de l'Ecran," par L. Ombredanne et R. Ledoux-Lebard. *Journal de Radiologie et d'Elect.*, March, 1916.

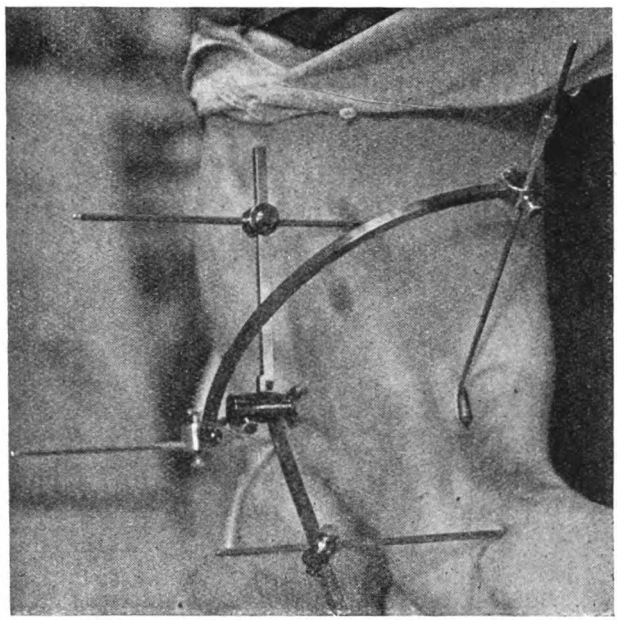


Fig. 2.

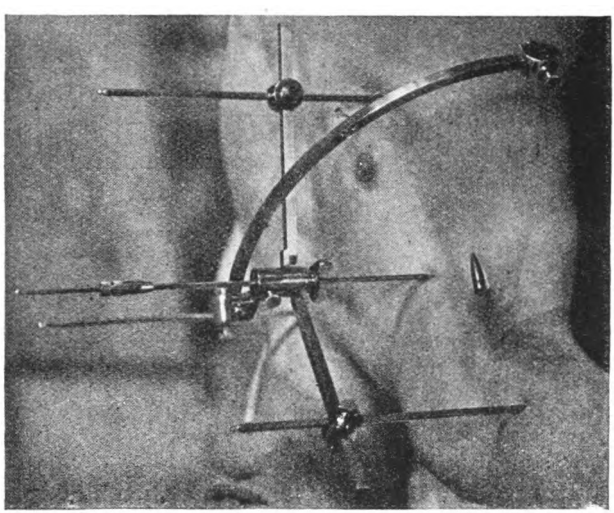


Fig. 1.

Illustration 43.

Fig. 1. Shows the adjustment of the central vertical probe.

Fig. 2. The use of the arc whereby the foreign body can be found from a lateral oblique access.

tube may be obtained by carrying an overhead set of trolley wires through the wall of the operating room, so that only the table, connections to the tube, and controlling switch to the primary of the coil need be in the operating room. Of course, if the operating room cannot be darkened, a cryptoscope must be used; the type in Illustration 44 is most suitable, and can be covered with a sterile cover. It provides, when lifted, a violet glass protecting the surgeon's eyes from loss of adaptation. In this way intermittent or continual screen control can be obtained.

If distance or structural difficulties prevent the realisation of this suggestion, and a portable X-ray installation, such as is used for the verification of position of fractures in the wards, is part of the equipment, then of course the difficulty can be overcome by its introduction into the theatre when needed. However, so much good work has been done by this technique, that many hospitals have found it desirable to equip a radio-surgical room with its own installation. A special table should be provided, with ample protection to surgeon, assistants, and anæsthetist, in the form of lead sheets. The illumination, preferably entirely electric, is provided by two separate clusters of high candle power lamps, under a foot control by the surgeon or his assistant; one group is white while the second is red or violet. The controlling foot switch, in its central position, illuminates the room with the red light, moved to the left it operates the tube, and to the right it puts in circuit the white light. In this manner the surgeon or his assistant (preferably the radiographer) has full control.

In practice, the patient is placed on the table for operation and anæsthetised, the tube roughly adjusted to the area of operation, and the sterile field prepared, draped preferably with a large sheet, with a central aperture for the operation. The sheet should hang down over the tube and diaphragm controls, which can then be adjusted by the surgeon himself from time to time, if necessary, during the operation. The latter part of the work can be carried out in a red light, and when all is ready, and the tube is switched on and the light out, perfect vision will be a matter of only a few seconds.

The points of importance are the protection of operators, a tube well covered with a small diaphragm and rigorously

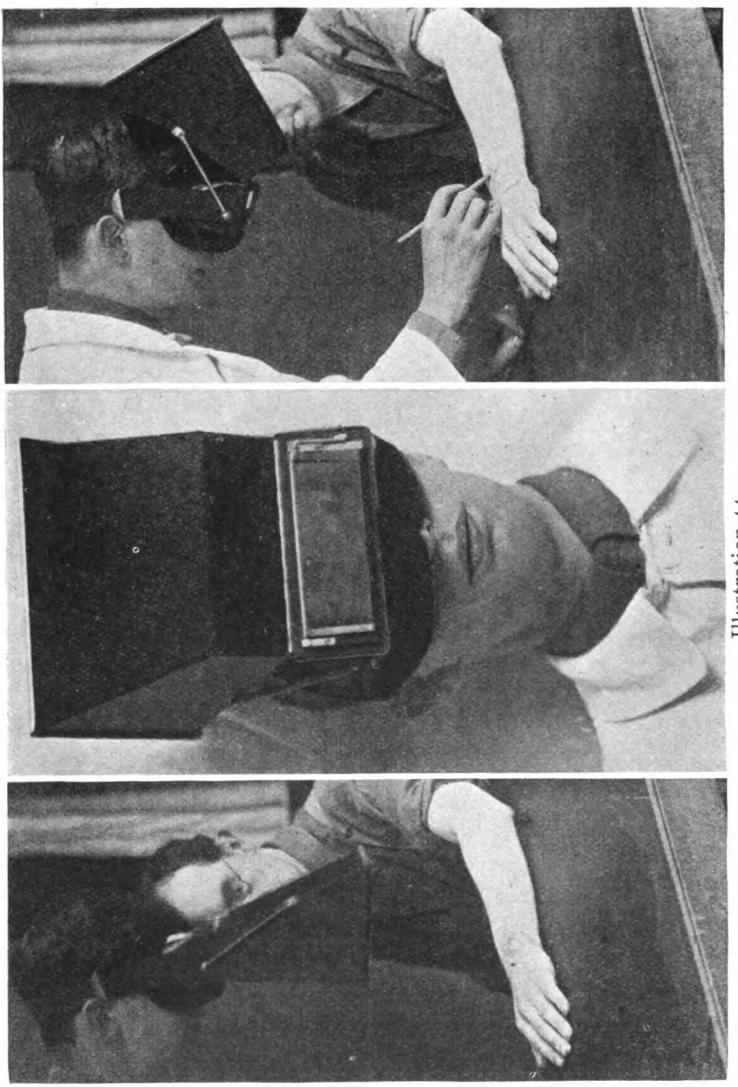


Illustration 44.

The cryptoscope raised to mark an observation.

The screen lifted disclosing the violet glass which falls automatically into position on the first upward movement.

The cryptoscope in use.

centered to ensure faithful projection of the image, long-handled instruments to keep the hands out of the pencil of

rays in use, hard rays, and a sheet of aluminium, or preferably a table with an aluminium top, to protect the patient.

The screen is best supported by an independent upright; when the foreign body is located the large screen may be exchanged for a smaller one, of some 10 cm. square, enclosed in a sterile bag, faced on the upper side with a celluloid window. Arranged in this manner it is but a small encumbrance to the surgical field.

This method has much in its favour for the removal of multiple lead splutterings, and superficial foreign bodies that

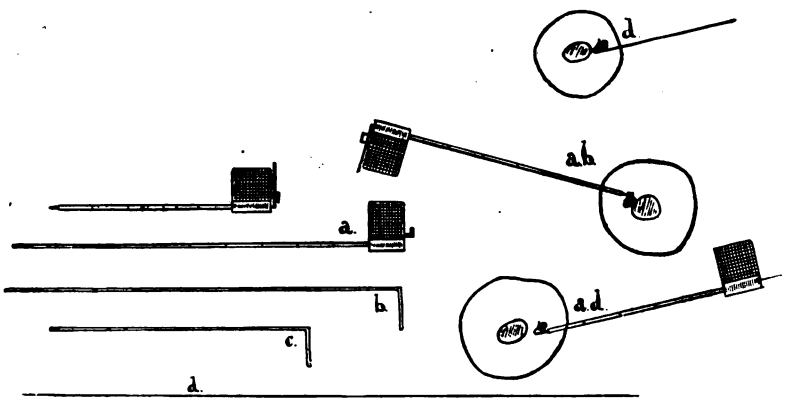


Illustration 45.
a. Canula; *b.* Sharp trocar; *c.* Blunt trocar; *d.* Fine stiff wire with barbed end.

do not vibrate, while the control it offers in difficult cases can hardly be dispensed with if one would be always successful. Foreign bodies in the lung that are operable are successfully removed by this technique in conjunction with a geometrical and anatomical localisation. As practised by Dr. Petit de la Villéon,* when once the skin is penetrated an alligator forceps is pushed through the pleura and into the lung until it touches the foreign body; when the forceps miss the foreign body, further observation is required to adjust their position; this may be done by displacement of the tube, or, as preferred by the author of this operation, by a rotation of the patient on his

* *Presse Médicale* May 31, 1917.

long axis, for which purpose a simple table has been made, the top of which pivots at will.

Sutton's Probes.

Closely allied to the preceding is the use of this little appliance, comprising a canula graduated in cm. and provided with a pointed and a blunt trocar (Illustration 45), which are supplemented with some lengths of stiff wire crooked at the ends.

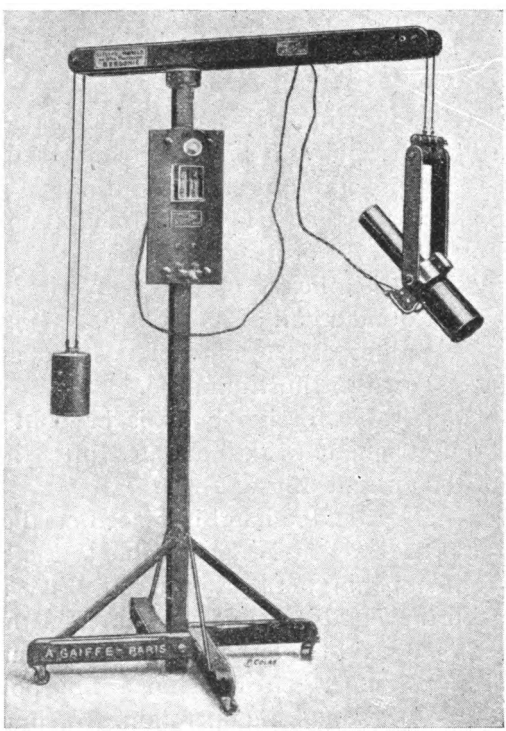


Illustration 46.
Bergonié vibrator with moving scaffold.

In use, the sharp trocar and canula is introduced under local or general anæsthetic, if necessary; and under control of the screen, the point of the trocar is placed on the skin coinciding exactly with the shadow of the foreign body, with the tube rigorously centered and the diaphragm shut down.

Holding the canula and trocar vertically, the point is introduced through the skin and the sharp trocar then exchanged for the blunt one, which is gradually advanced until the foreign body is reached; at this point the trocar is removed leaving the canula in contact. Through the latter is threaded one of the wires, which being retained by its hooked end catching in the tissues, permits the canula to be removed without disturbing the relation of the wire to the foreign body. The patient is then taken to the operating room and the wire used as a guide to the foreign body.

Bergonié Vibrator.

This is a large powerful electro magnet, actuated by alternating current, and requires for its effectual working some 60 amperes, at 110 volts, with a periodicity of about 50. When in operation, a heavy magnetic field of attraction and repulsion is produced over the area of its core.

In construction it is a heavy core of iron wires, about one end of which is wound a coil of many turns. It is suspended from the ceiling, wall bracket, or movable scaffold, and presents the appearance shown in Illustration 46.

When a magnetisable foreign body is brought within the rising and falling magnetic field, it pulsates in rhythm with the periodicity of the current in use.

To locate a projectile, the hand is placed on the limb and the vibrator approached as near as possible to the back of the fingers without touching (Illustration 47, Fig. 1). If no vibration is felt the hand or fingers are pressed more firmly into the tissues. When found, the point of maximum vibration is located with one finger, and the skin at this point marked to save time in relocating at the operation. A simple wooden table is preferable, to avoid the disturbance of the magnetic field which is caused by one of iron, and the limb should be so placed that muscles are relaxed and flaccid, so as to impose as little resistance to the pulsation as possible.

At the operation the vibrator should be provided with a sterile cover. The surgeon should confirm the previous localisation mark made, and make the incision through it, if

possible, progress being directed by repeated applications of the vibrator, the pulsation increasing as the fragment is approached (see Illustration 47, Fig. 2).

It is also useful, during an operation, in finding foreign bodies which have been otherwise localised, and which were too deep to be vibrated until approached in the operation.

It is obvious that this procedure is only practicable with

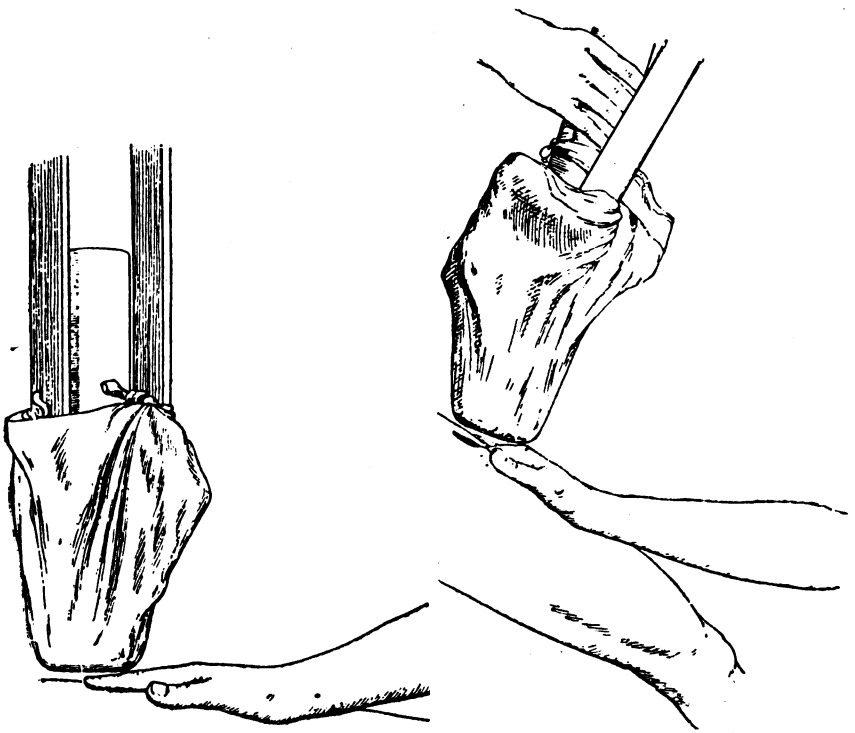


Fig. 1. Fig. 2.

Illustration 47.

Fig. 1. General Exploration. Fig. 2. Exploration of a wound.

metals or alloys that will respond to the magnetic field, but, with the exception of lead, most other projectiles will respond to a greater or lesser degree. Some skill in touch will be required to appreciate the vibration of a tiny fragment. Non-magnetisable clamps must be provided, or vessels ligatured and instruments removed, before bringing the vibrator into the field of operation. It must be realised that it is only a

vibrator, and will not attract and withdraw a projectile from a wound.

The vibrator heats rapidly from the heavy current, and it must be cut off frequently to allow it to cool. No individual séance should be longer than two minutes.

A second form of this magnet, modified in its winding, and with the addition of condensers, is an advantage where the

Illustration 48.
Electric probe in use.

alternating main does not change its pressure to a marked degree. Should this occur, the condensers are liable to break down and give trouble ; otherwise it is to be preferred. It is quite as powerful, if not more so, and the current consumption being only about 7 amps., it can be run for a longer period without rest.

Telephone Probe.

This is a valuable addition to the surgeon's equipment, and should always be at hand in all operations for removal of foreign bodies. By its use he is enabled to differentiate metallic substances embedded in the tissues from bony structures or fragments that may be near to or surrounding the foreign body; it is very simple in construction and in use.

It comprises a telephone receiver, double for preference, mounted on a head piece (Illustration 48, A). Connected to the receiver are flexible insulated wires, about 2 metres long; to one is connected a carbon plate (*B*), about 14 by 5 cm. (a bichromate battery carbon will do well). The other flexible wire is best provided with some simple connection (*C*) to which can be easily attached an additional length (about 50 cm.) of sterilisable flex, provided at its other end with a clip (*D*) to grip instruments in the field of operation.

The detachable section of flex is sterilised with the surgical instruments. The carbon plate is wrapped in gauze and well saturated with a strong solution of common salt and fixed by a bandage, or placed under the patient in good contact with the skin. The axilla and between the thighs are good positions when possible; the moisture provided by the large glands reduces the resistance to the current. If preferred, a round rectal electrode may be provided. The receiver is placed upon the surgeon's head and the sterile section connected up. Any surgical instrument can now be brought into the circuit by attaching it to the spring clip. When the instrument, so attached, is introduced into a wound, a momentary contact with a metallic foreign body will declare itself by a clicking sound in the earpiece, or a grating sound will be produced by a rubbing contact, a small current being generated sufficient to actuate the receiver. The body forms the electrolyte between the (positive) carbon plate and (negative) foreign body. Should a probe have been used to explore it may be replaced by forceps and the extraction controlled in the same manner.

Care should be taken that the operator is not confused by touching other instruments in the field, and mistaking the

sound for contact with the foreign body. Retractors and clamps are best removed; the telephone can be tested for its efficiency at any time by contact with an instrument in the wound.

La Baume Magnetic Finger Cot.
(For use at Operation.)

This apparatus, while not so useful as the probe, yet has its sphere in locating foreign bodies in the pleural cavity or abdomen, or exploring a large wound in which a foreign body may be free. It lacks the sense of definite direction, but is very convenient for exploration, as it renders audible a metallic fragment at a distance of about 1½ cm. The volume of sound increases as the distance separating the finger cot and the foreign body is decreased. It is particularly useful should a foreign body be lost in a cavity, or an incision carried beyond the depth at which a fragment has been localised, to disclose on which side the foreign body lies.

Suggestions to X-ray Operators.

Examinations should be made as exhaustive as possible to prevent the necessity of repetition.

Every report and localisation chart should bear the date and the serial number of the patient.

Reports on first observations for foreign bodies should state if in the radiographer's opinion they will vibrate. They should be vibrated by the doctor in charge of the case who will subsequently operate. His knowledge of the case and previous marking up will be useful. If the foreign body does not vibrate it must then be localised.

Reports of foreign bodies should state all the definite information ascertained, and ambiguity should be avoided. If plates were taken it should be stated, and their direction mentioned. The size of the foreign body should be given, and in what tissues it lies, soft or bony, etc. All localisations should be both geometrical and anatomical, and be accompanied by a chart marked with "right," "left," "anterior,"

"posterior," and any other necessary information, such as the vertebral level in the case of the trunk. The chart should also be marked, when possible, with the wound of entrance. The report should include the nature of the projectile, viz., piece of shell, rifle bullet, shrapnel ball, etc., and its size; if it moves with respiration, arterial pulsation, flexion, extension; if it can be felt or moved from the skin, and in what tissue it is embedded. In all difficult and serious cases some effort should be made to check the findings, and in the transferred contour method no foreign body should be considered localised if the three lines do not intersect within the area of the foreign body and in the same plane. All localisations should state the position of the limb or body when the observations were made.

Nitrate of silver sticks may be used for marking the skin, and if it is desired to render the marks visible at once they may be touched with photographic developer; this in some measure will help to prevent blistering. The mark should be made small and as neat as possible; indelible ink, or tattooing with Chinese ink, has been resorted to; the ideal marker has not yet been found.

The doctor in charge of the case should see that these marks are kept up, and the nurse warned that they are not to be accidentally scrubbed off in the surgical preparation. Nothing is more annoying to all concerned than the arrival of a patient on the table with his marks carefully removed.

Cases for localisation with open wounds should be sealed with collodion dressings as small as possible.

The surgeon should make himself thoroughly acquainted with the localisation data and skin markings before the operation, and with the principles and methods employed, that he may be able to appreciate and use the information placed at his disposal.

Where possible, surgical approach should be made to a foreign body from the aspect that presents the largest surface.

APPENDIX I.

AN AUXILIARY SWITCH-BOARD AS AN AID TO SHORT EXPOSURES.

A large number of hospitals are equipped with their own electric lighting plant and are far removed from electric mains,

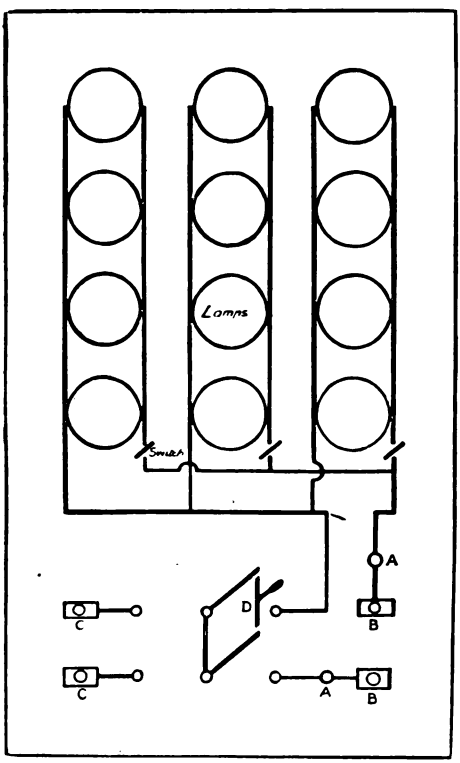


Illustration 49.

Wiring of the Switch-Board for 15 amps.

B.B. Main terminals connected to arrival terminals of main to X-ray installation.
A.A. Fuses.
D. Double pole knife switch.
C.C. Connection to primary closing switch of control of X-ray installation.

and are not provided with accumulators. This condition often places the X-ray department at a disadvantage for making

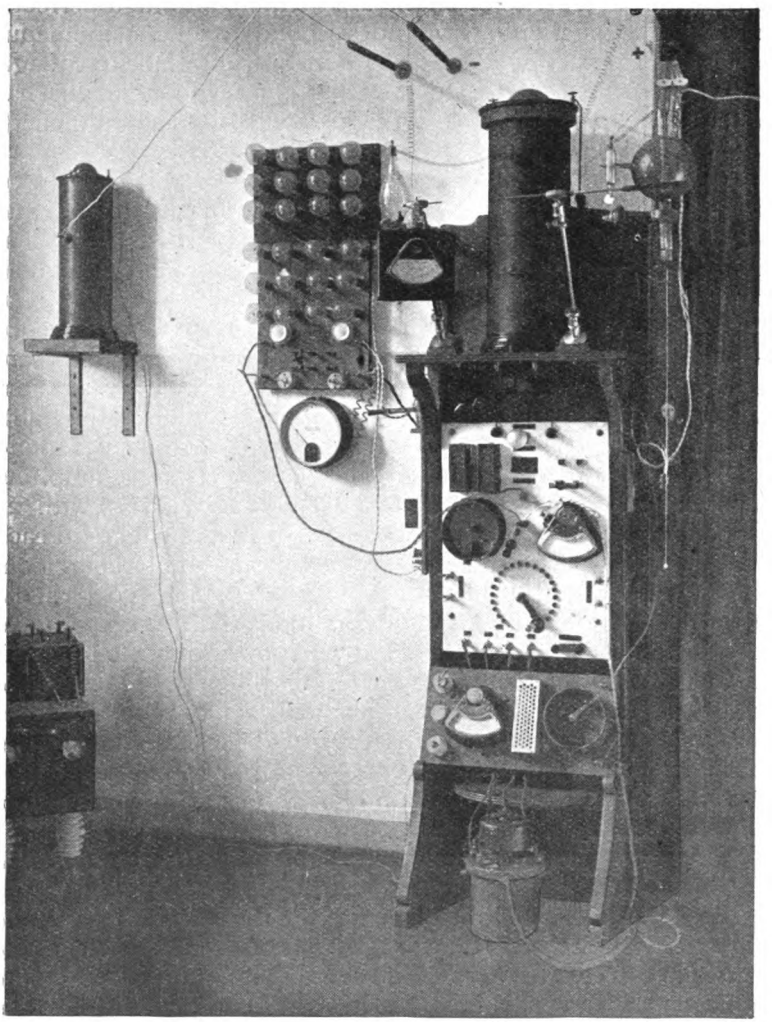


Illustration 50.

Shows the installation and general connection complete.

On the left will be seen the lamp board.
Connection on the right to main.
Connection on the left to primary.

short exposures so necessary in chest and kidney work, the reason being that hardly ever is a compound wound dynamo installed, but a series or shunt type which, although perfectly satisfactory for lighting, will not respond to an instantaneous call of the necessary current without a heavy fall in voltage, and by the time that the engineer or automatic regulator has been able to speed up to the demand, the radiographer's opportunity has passed.

Being similarly situated at one time, and explaining to an assistant why we were unable to use the intensive switch and small self-induction on our apparatus, I happened to say that if the department had the control of the house lighting switch, and could simultaneously switch out the house light and divert the current to our coil, our difficulty would in a measure be solved. It was actually solved in the simple switch-board shown here, which is fixed by the side of the X-ray installation, and conveniently placed, so that the switching off of the lights and closing of the primary switch can be easily done. I found that the demand of the small self-induction was 30 amp. A board was made for me by Maison Gaiffe, of Paris, with 24 50 C.P. carbon lamps in parallel, with separate switches to each four lamps to switch them in gradually, the supply being connected to the arrival supply to the X-ray plant. To design a board suitable for any given installation it is necessary to know the demand made upon the main when operating the low self-inductance of the coil, and to put in the number of lamps required; four 50 C.P. carbon filament lamps, at 110 V., consume about 5 amps. So it is easy to determine the number of lamps necessary.

In all installations of this kind it is necessary to fix a protection condenser to the dynamo.

The accompanying diagram will illustrate the connections for the switch-board.

To operate the board, throw in the knife-switch *d* to the right, and switch on the first four lamps. As each set of lamps is put into the circuit, there is a temporary drop in the voltage; as the machine speeds up the voltage rises to its original value, and then further lamps are switched on. In the case shown in Illustration 42, when all the 24 lamps are burning at full pressure the dynamo is giving an additional 30 amps. at 110 volts, which is now at our disposal. If the knife-switch *d* is now thrown over to the left, the lamps are cut out of the circuit, and the whole 30 amps. is thrown into

the small induction primary of the coil, which will then give a current in the secondary several times larger than is obtainable in the normal working of the dynamo. When the exposure is finished, the switch is thrown back to the right; and if the heavy current is not further needed, the lamps are cut out gradually by means of the small switches.

A voltmeter is an essential part of the installation, and must be mounted, should there not be one already, so as to check the rise and fall in pressure.

APPENDIX II.

RADIOGRAPHS DIRECT ON BROMIDE PAPER AND THEIR PLACE IN WAR ECONOMY.

Limitations of Bromide Paper.

It should be understood from the beginning that the use of bromide paper to replace plates in radiography is limited. It is absolutely unsuited for fine detail and the diagnosis necessitating fine detail, such as injuries to joints, doubtful fractures, bone diseases, sequestra, etc. For it must be recognised beyond all doubt that a radiograph direct on bromide paper, or a print from a negative, viewed as it is by reflected light, can never show delicate gradations of tone and detail like a plate viewed by transmitted light. It is admitted, then, that plates (or films) are imperative for fine diagnostic work, but all war radiography is not of this kind. Civil practice is largely so, and, as a result, many radiographers are grossly prejudiced against bromide paper, and fail to see its use and advantages in certain branches of war radiography. Nevertheless, direct bromide radiographs have, beyond doubt, a field all their own from the point of view of efficiency and economy. Illustrations 51, 52, 53 and 54 suggest the possibilities.

Indications for Use.

There are two large demands made on the radiographic service which bromide paper can admirably fill, namely, the demonstration of foreign bodies and of fractures.

At the advanced field hospitals many fluoroscopic observations are made for both these purposes—a search for foreign bodies, and an examination for the position and nature of fractures, and the alignment of fragments. A large percentage of such work is on the limbs, and the routine varies with different units. In many cases, most of the fluoroscopic observations are followed by a plate, and a report is made, upon which the subsequent operation and treatment are based. Evacuation of the patient follows, with a report (often ambiguous and conveying little to the medical officer who receives the case) of the condition that led to the treatment or operation practised, such as resection, sequestrectomy, etc. What

would the medical officer receiving a case not give to see the radiograph upon the evidence of which the treatment has been practised? What would not be gained in judgment, progress, and results, were the radiographic records complete in every case? Patients are perforce at times evacuated before their plates are dry; bromide radios can be blotted, and dry very quickly.

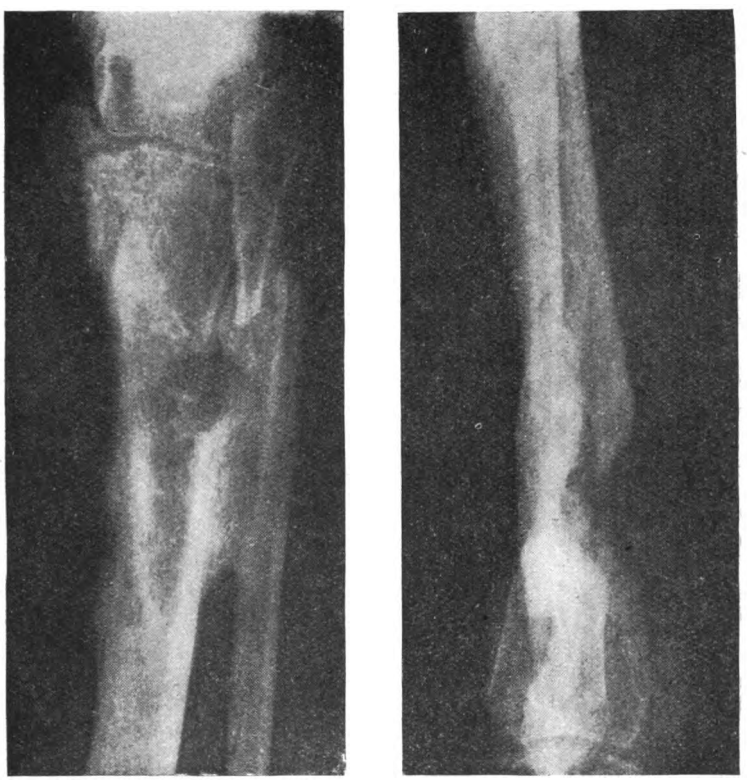


Illustration 51.

Antero-posterior and lateral direct radiographs on bromide paper. These pictures give an idea of the amount of detail that can be obtained. Sequestra, osteomyelitis and rarefying osteitis are well demonstrated.

I submit that here is the place for direct bromide radios. At the time of these first injuries in the shaft of the bones there are few fine details to diagnose; large sheets of bromide paper may be used, and this has the advantage of including the articulations at both ends, which will then disclose the

nature and the degree of any displacement present. Antero-posterior and lateral views may be taken side by side on the same sheet. The development takes but a minute; and as the saving of time and labour at the front is important, during a rush of work, this is a great gain; moreover, if so desired, the time saved can be used to make prints from negatives, where

Illustration 52.

Radio for position of fragments. Femur.

Bedside radiograph taken with portable apparatus passing 2 M.A., 42 M.A.S. Penetration equivalent to 3½ inch spark-gap, distance 22 inches.

plates have been necessary to decide as to the involvement of a joint. When so made these radios complete the records of the case, by providing the earlier observations which are so frequently absent.

There are still many surgeons who prefer, in spite of the

mathematical accuracy of improved localisation methods, to operate for the removal of foreign bodies by the information gained from antero-posterior and lateral plates; or it may be desirable, in conjunction with a localisation, to record the relationship of a foreign body to some bony landmark in a radiograph. For these purposes the use of plates is unwar-

Illustration 53.

Radio of humerus for position of fragments. Antero-posterior and lateral. Taken in bed. Portable apparatus passing 2 M.A. 18 M.A.S. Equivalent spark-gap 2½ inches, distance 17 inches.

ranted extravagance, bromide paper giving in every respect the same information.

To follow our patient a stage further, the next demand on the department is to verify the position of the fracture on admission to a hospital; and should he be transferred to an

apparatus for treatment by extension and suspension, he will need to be radiographed in the apparatus as he lies in bed; it is well known that an extra kilo in extension pull, or a slight change of angle, may mean all the difference between a fair and an excellent result. For this work bromide paper is ideal; sheets may be used large enough to include the articulations, with antero-posterior and lateral radiographs on the same sheet, as before mentioned, and in this way the results of

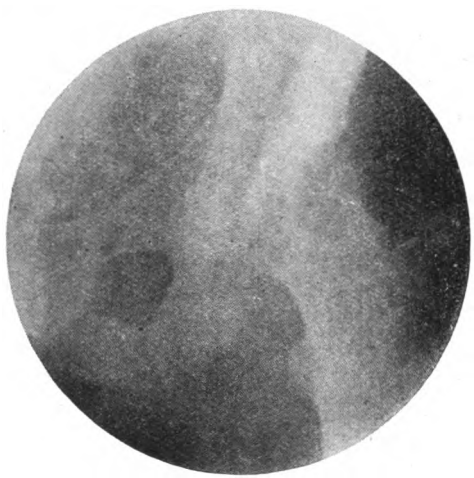


Illustration 54.
Direct bromide radiograph of hip-joint, 65 M.A.S., equivalent spark-gap 4 inches, distance 20 inches.

treatment may be checked so as to give the best possible result in the alignment of the fracture.

When the time comes for final results, these can again be radiographed on bromide paper, so as to complete the papers of the case.

Where it is desired that one radiograph shall be retained and a second shall go with the patient's papers, two bromide radios can be taken at the same time, as explained below under technique.

All these observations can be made, compiling valuable data and ensuring the best results obtainable, and at the same time the expenditure involved will be only a tithe of the cost of the plates that are saved.

From time to time radiographs will be needed to determine

the presence of sequestra, osteomyelitis etc. For this work nothing short of the best plates and films will suffice.

Technique.

The bromide paper should be the most rapid positive paper that can be obtained (of the carbon or contrast type), and a surface about the same as that of a plate is to be preferred to an enamel surface.

Intensification Screens should always be used, not only on account of the reduction of the exposure, but because the print is of a far better quality, being richer in detail and contrast.

The tube penetration should be about 15 to 20 per cent. less than the recognised penetration for plates. Too hard a tube makes the print foggy and flat. Suitable penetration is an important factor.

The exposure will, of course, vary with different papers; it should be approximately from $\frac{1}{5}$ to $\frac{1}{3}$ of that required for a plate under the same conditions, but without a screen. Over-exposure is to be avoided. The best exposure can be soon found with any special paper.

Development is another important consideration. If metol hydroquinone developer is being used for plates, and it usually is so, it will answer perfectly for these prints; in this way no extra dishes or solutions are necessary. Some extra bromide is the only addition needed.

Development is complete in from one to two minutes, and several prints can be developed at the same time, which should be appreciated when there is a rush of work.

If two copies are needed, two screens in the one cassette at the same time will meet the case, and little difference can be observed in the resulting radiographs. It is not necessary to have special screens for the smaller sizes, as the bromide paper for radiographs of the long bones can be cut in halves lengthways and placed in the cassette, without any risk of scratching the screen, as plates so used would do. If at a later date extra copies should be required, photographic copying on the same or a reduced scale may be resorted to. Intensification may be practised if a print needs strengthening. If so desired, a print may be treated with wax and used to print from in the same manner as a glass negative. Such treatment is really superfluous, as excellent contact prints can be made without any preparation.

Stereoscopic radiographs, made with the usual technique of tube displacement, can be viewed with a Pierre stereoscope, or if this useful little instrument is not on hand, resort can be made to the mirror bisector principle (see p.41, Illustration 31). For the production of radiographs to be so viewed, the rays pass in the first exposure through the bromide paper to the screen, and in the second through the screen to the bromide paper.

For economy in radiography of the long bones half sheets may be used.

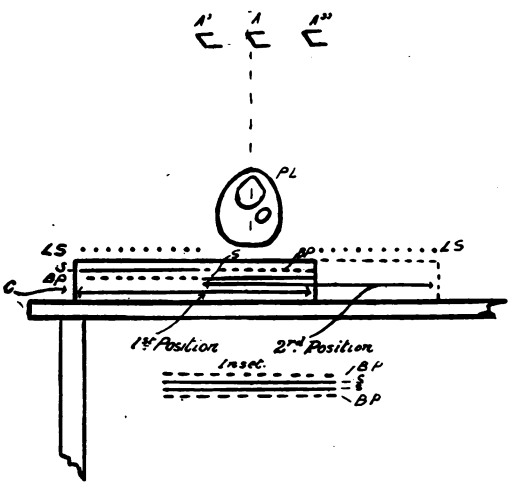


Illustration 55.

Stereo radios direct on bromide paper. Technique of production. Single copy.

A. Central position of tube. *A' A''*. Displacements right and left. *PL*. Patient's limb. *C*. Stereoscopic cassette carrier. *LS*. Lead sheet. *BP*. Bromide paper. S. Intensifying screen. *Inset*. Position of screens and bromide paper for production of duplicates.

If duplicates are required, two screens and two sheets of bromide paper may be suitably arranged in the cassette, so that the rays pass through one sheet of bromide paper to the first screen, and through the second screen to the second sheet of bromide paper.

The radiographs are afterwards cut; the left half of the first and the right half of the second form a stereoscopic pair, as do also the remaining two half sheets. If only one stereoscopic

copy is needed, a screen may be cut in halves and kept specially for the purpose; the half screens and the bromide half sheets are placed side by side in the cassette, the paper lying on top of the screen on one side, and the screen on top of the paper on the other. (See Illustration 55.) The two halves are exposed in turn, one half during each exposure being covered with lead, as explained above (pp. 41, 42).

The arguments in favour of the use of bromide paper may be briefly summed up as follows:—Glass is getting increasingly scarce, and old negative glass used over again produces an unsatisfactory plate. The breakage of plates in transport and in the department is considerable; weight, packing, space, and labour of transport are serious questions, cost being last but not least.

In contrast, 100 sheets of bromide paper occupy less space and weigh less than six plates, a great economy of money, time, and material is effected, and the radiographs can accompany the patient and make his history complete. Large radiographs can be taken more frequently to determine the position of a fracture, thus greatly increasing the efficiency of treatment, and improving the results, since the cost at present renders the free use of plates for this purpose impossible.

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Short exposures, aid to 72

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